MINERS' PHTHISIS.

Reports

of an

Investigation at Bendigo

into the

Prevalence, Nature, Causes and Prevention of Miners' Phthisis

and

The Ventilation of the Bendigo Mines.

BY

Walter Summons, M.D., B.S.,

under the direction of

The Bendigo Hospital Committee

and at the cost of

The Trustees of the Edward Wilson Estate,

Melbourne 1906.

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REPORT

TO THE

COMMITTEE OF THE BENDIGO HOSPITAL

ON AN

INVESTIGATION AT BENDIGO

INTO

THE NATURE, CAUSES AND MEANS OF PREVENTION OF MINERS' PHTHISIS.

The Committee of the Bendigo Hospital.

Gentlemen,—

I have the honor to submit for your consideration the following report on the results of my enquiry into Miners' Phthisis:—

The investigations extended over a period of six months, and the report presents in detail the results of my research into the clinical and pathological aspects of the disease, as well as a review of the conditions of work underground. This latter was treated of in a preliminary report. The home life of the miners is also briefly discussed.

The trustees of the late Edward Wilson's estate, by instituting the inquiry and meeting all the necessary expenditure, have placed the whole mining community under a deep debt of gratitude, and deserve its warmest thanks.

The subject has been dealt with under the following headings:—

1. Statistical.
2. Symptoms.
3. Pathology.
4. Etiology.
5. Prognosis.
6. Prophylactic measures.
7. Summary and recommendations.

STATISTICAL.

For the determination of the extent to which phthisis and respiratory diseases prevail amongst the Bendigo miners, the death registers of the district were perused, the search being carried backward for 30 years. This period was chosen, as, prior to the year 1875, machine rock drills were not in common use. Up to that time, holes for blasting had been made by hand drills. With the introduction of the machine drill, which enabled mining operations to be carried on with much greater rapidity, the amount of dust produced underground was largely increased. During the period there has been a marked increase in the number of miners dying of lung diseases, notably tuberculosis.

Though the health of quartz miners has long been known to be unsatisfactory, it is chiefly of recent years that alarm has arisen at the extent to which lung diseases prevail. It was this widespread feeling that prompted the trustees of the Edward Wilson estate to institute an enquiry into the subject at Bendigo. The suspicions have been confirmed, and the need for their public-spirited action justified by the results of the statistical enquiries.

To Dr. B. S. Cowen, of Eaglehawk, I am deeply indebted for his kindly interest in the investigation, and for his valuable assistance in collating the statistics of that town. Also, my thanks are due to Mr. E. T. Drake, the Government Statist, for furnishing me with Tables III. and IV. From the returns sent in to the Mines Department a very fair estimate was arrived at of the number of quartz miners employed at Bendigo from year to year. The number has varied for several reasons, especially owing to the exodus and return of men from the West Australian fields. The lowest was 2850 in the year 1890, and the highest in 1899, when there were 3990 on the field. At the present time there are 3650 miners.

Table I.

Total Deaths Amongst Bendigo Quartz Miners, 1875—1906.

Year.	Miner's Phthisis. (Tubercuulous).	Average age at Death of those in the previous Table.	Chronic Bronchitis.	Acute Pneumonia.	Total deaths from Respiratory Disease.	Fatal Mining Accidents.	All Other Causes.
1875	14	45·8	2	8	24	7	26
1876	15	46·4	0	7	22	9	33
1877	17	45·3	5	4	26	9	24
1878	20	44·0	5	5	30	9	26
1879	19	47·8	2	12	33	8	30
1880	12	45·0	1	2	15	13	29
1881	18	50·5	4	17	39	19	31
1882	25	44·8	7	5	37	8	38
1883	26	49·7	5	3	34	16	30
1884	23	48·1	7	6	36	8	26
1885	23	48·3	9	13	45	7	30
1886	20	49·8	21	8	49	10	27
1887	19	50·4	9	3	31	11	39
1888	30	51·9	12	2	44	10	36
1889	28	51·8	8	5	40	9	35
1890	23	51·8	11	3	37	9	36
1891	24	54·9	15	5	44	4	49
1892	26	53·0	10	7	43	11	31
1893	35	53·2	10	7	52	13	42
1894	32	53·5	11	6	49	10	41
1895	40	51·8	10	9	59	7	50
1896	44	56·2	15	13	72	12	49
1897	29	52·4	9	11	49	5	55
1898	40	55·1	18	6	64	10	58
1899	34	54·4	13	11	58	6	51
1900	43	51·6	6	11	60	7	32
1901	32	53·5	9	2	43	2	49
1902	46	49 9	9	7	62	12	25
1903	30	54·4	10	6	46	5	44
1904	33	49 2	8	13	54	1	26
1905	47	51 2	12	8	67	4	26
1906½	24	48·4	7	7	38	1	12
		Total ..	..	..	1,402	272	1,136

Table II.

Annual Deaths amongst Bendigo Miners, determined in 5-year periods, and estimated as per 10,000 *living at all ages.*

Year.	Miners' Phthisis (Tub'c'lous)	Chronic Bronchitis.	Acute Pneumonia	Total Lung Diseases.	Fatal Mining Accidents.	All Other Causes.	Total Deaths.
1875—79	48·5	8·0	20·5	77·0	28·5	74·3	179·8
1880—84	56·9	13·1	17·0	87·0	32·8	70·6	190·4
1885—89	80·0	39·3	20·6	139·9	31·3	111·3	282·5
1890—94	84·6	34·4	16·9	135·9	28·4	120·2	284·5
1895—99	102·4	35·6	27·4	165·4	21·9	130·4	317·7
1900—04	100·8	23·0	21·3	145·2	14·7	96·5	256·3
1905-6 (½)	129·6	34·6	27·4	191·6	9·2	69·2	270·0

Annual Deaths from Pulmonary Diseases amongst Bendigo Miners. Rate per 10,000 *living Miners.*

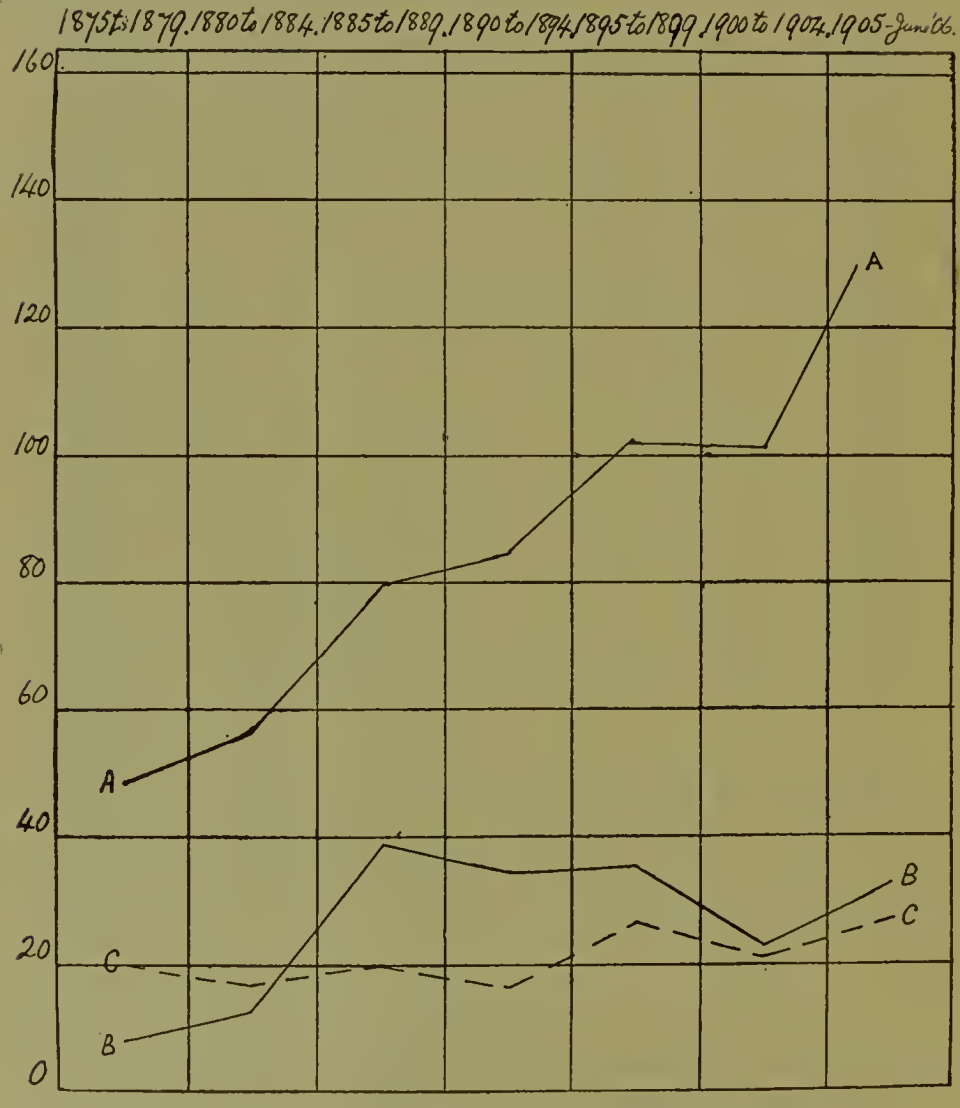


CHART A.

AA Miners' Phthisis (tuberculous). BB Chronic Bronchitis.
CC Acute Pneumonia.

Annual Deaths amongst Bendigo Miners. Rate per 10,000 *living Miners.*

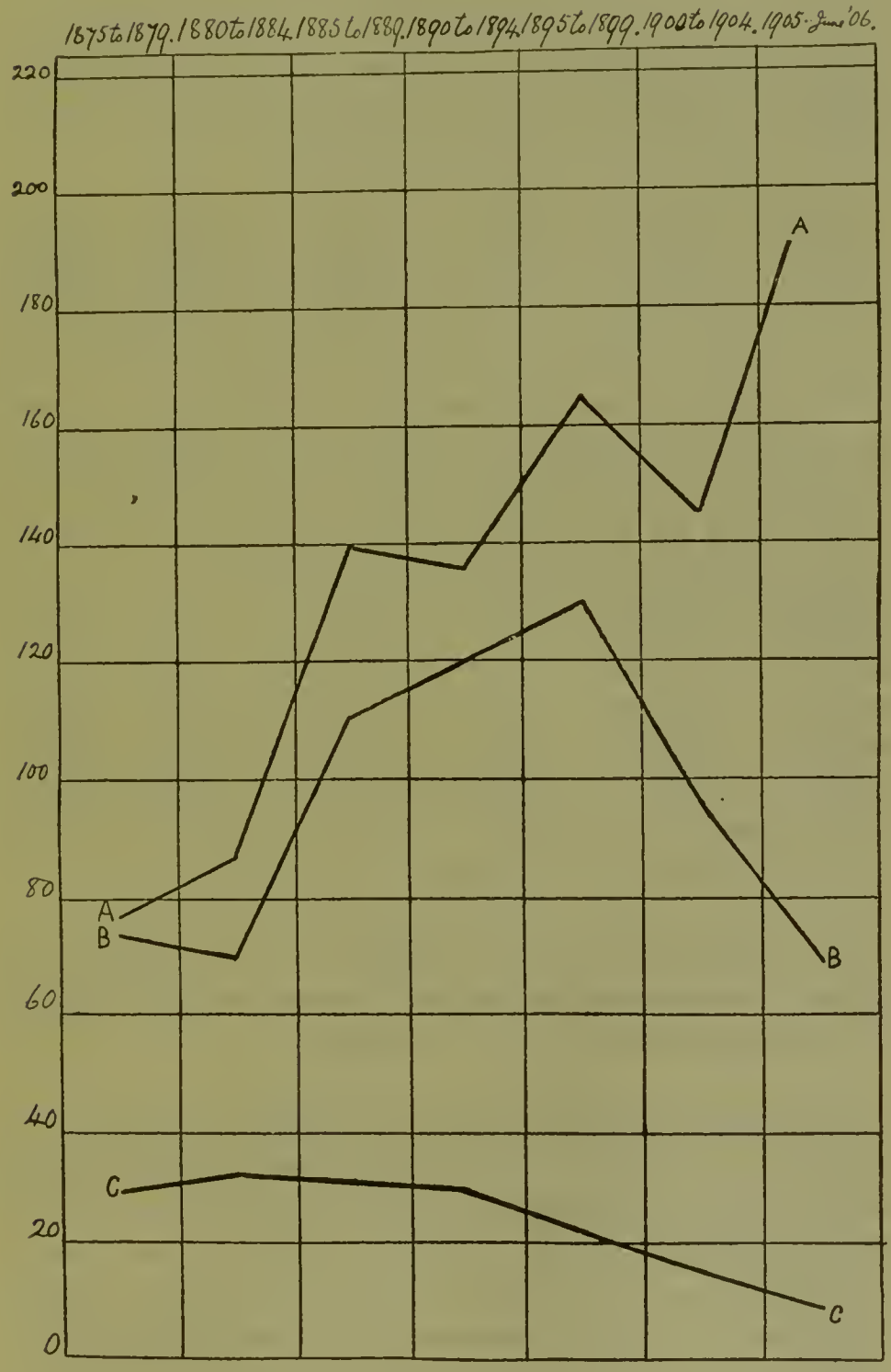


CHART B.

AA, Pulmonary Diseases. BB, all Other Diseases.

CC, Fatal Mining Accidents.

The above figures indicate a marked increase in the number of deaths due to pulmonary disease, more especially tuberculosis. Prior to 1880 the detrimental effects of the machine drills had not become manifest. But, since their coming into general use, the increase in the death rate has been progressive, and during the last 18 months it has been so excessive that the outlook is indeed fraught with the gravest forebodings.

The total number of deaths recorded as resulting from tuberculosis of the lungs is 891, while those from chronic bronchitis amount to 280; and, as shown in the clinical notes, these, with more accuracy, should be classed as tuberculous. The two groups of cases of necessity have been considered apart. Acute pneumonia also is tabulated by itself, and, as is seen by Chart A, its prevalence shows but little variation. The total deaths from lung diseases has risen from a rate of 77·0 to one of 191·6 per 10,000, and this is largely accounted for by the increase in the tuberculous diseases, which, represented by 48·5 in the first period, now amounts to 129·6. This increase is overwhelming, and out of all proportion to the annual mortality rate from consumption amongst adult males. The corresponding mortality for Victoria as a whole is less in 1903-05 than at any previous time; this is clearly shown in Table III. Table IV. gives the adult male mortality (miners and non-miners) for Bendigo alone.

The death rate has been estimated per 10,000 living for greater convenience of comparison. There are, as a matter of fact, only 3650 miners employed at Bendigo.

Unfortunately, no record is kept of the ages of the people at Bendigo, and on that account it has not been possible to determine the death rates in age groups, not even in the census years. The above table, however, clearly shows the enormous increase in the deaths amongst miners from pulmonary diseases, notably tuberculosis. On the other hand, fatal mining accidents are rapidly becoming fewer in consequence of the greater precautions taken in safeguarding the life of the miner.

These results can be more comprehensively seen by Charts A and B.

Table III.

Average annual number of deaths from Phthisis per 10,000 *population in Bendigo City, Eaglehawk, and Kangaroo Flat,* 1870 *to* 1905.

Years.	Annual mortality from Phthisis per 10,000 of the population.				
	All ages.			Males aged 21 years and upwards.	Females aged 18 years and upwards.
	Males.	Females.	Total.		
1870–72	19·85	12 80	16 61	35·33	24·32
1880–72	28·83	10·41	19·66	60·44	18·58
1890–92	40·29	15·28	27·41	77·90	24·93
1900–02	41·56	13·00	26·74	77·36	19·11
1903–05	33·25	12·03	22 24	62·29	17·52

Table IV.

Average annual number of deaths from Phthisis per 10,000 *population in Victoria,* 1870 *to* 1905.

Years.	Annual mortality from Phthisis per 10,000 of the population.				
	All ages.			Males aged 21 years and upwards.	Females aged 18 years and upwards.
	Males.	Females.	Total.		
1870–72	12·90	10·58	11 85	22·15	19·61
1880–82	15·22	12·69	14 02	26·89	21·08
1890–92	16·73	11·51	13·72	26·37	17·98
1900–02	13·56	9·80	11·69	23·18	14·88
1903–05	12·30	9·26	10·78	20·81	13·81

By comparing Table IV. with Table II. it is seen that the number of deaths amongst miners from tuberculosis is, at the present, six times as great as amongst adult males in Victoria generally. This affords ample evidence of the detrimental conditions under which quartz mining is carried on. Also, while the prevalence of the disease is diminishing amongst the general population, the number of miners affected is rapidly increasing. The ill-effects are even more reaching, and tuberculosis, in spite of the health-giving climate of Bendigo, is in excess amongst non-miners as well. The female death rate best exemplifies this. Throughout Victoria the number of deaths per 10,000 females living is 9·26, while the corresponding number for Bendigo is 12·03, and it was noted that many of the miners' wives were carried off by tuberculosis. Owing to these increased rates, Bendigo had a total consumptive death rate in 1903-05 of 22·24 per 10,000 of population, as compared to 10·78 for the whole of Victoria, whereas in 1870-72 the corresponding figures were 16·61 and 11·85 respectively.

Deaths due to Phthisis per 10,000 *of General Population,* 1889 *to* 1905.

Victoria and Principal Cities.

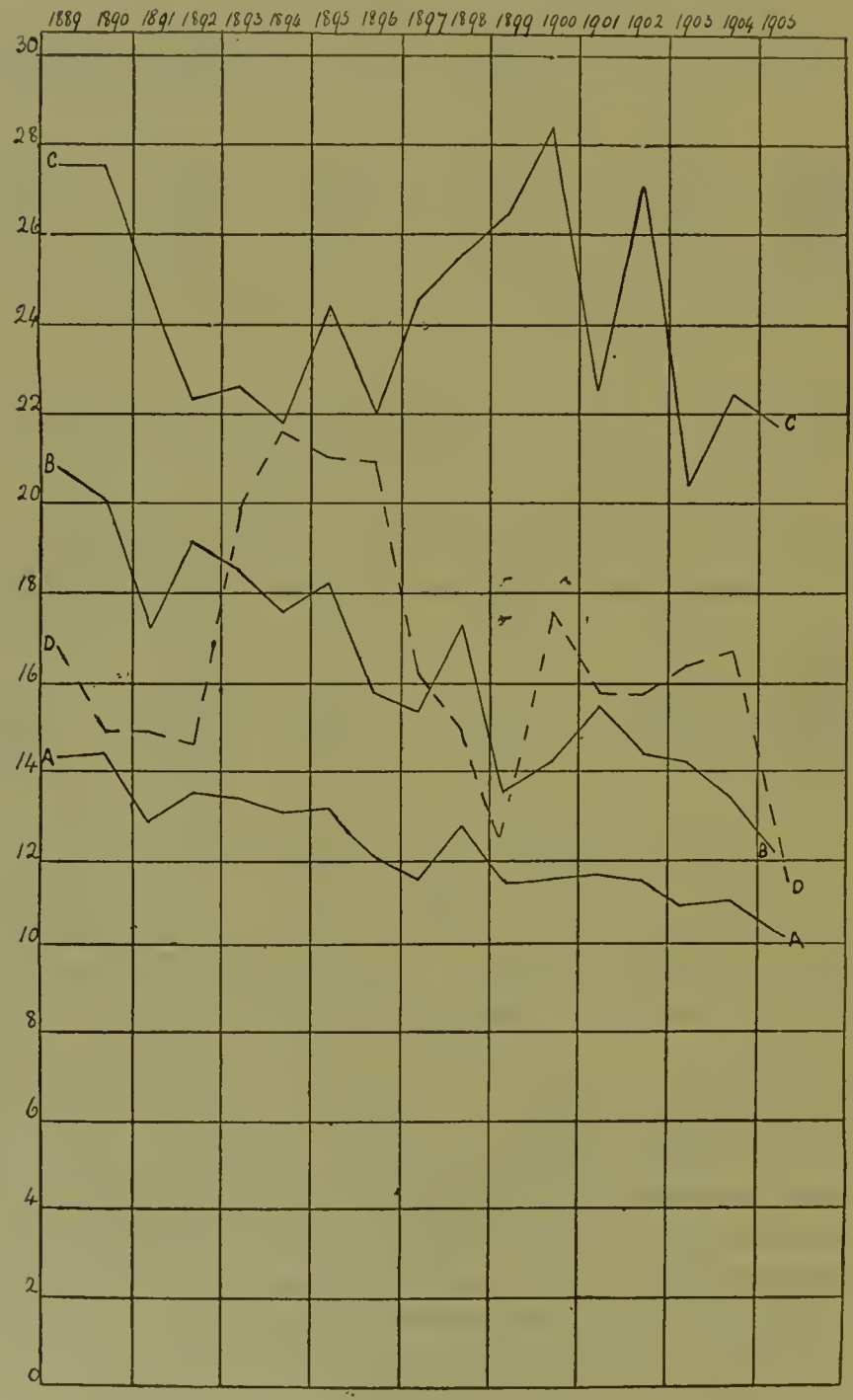


CHART E.

AA, Victoria. BB, Melbourne. CC, Bendigo. DD, Ballarat.

Through the courtesy of Dr. Norris, Chairman of the Board of Public Health, Chart E is included in the report. It graphically shows the phthisical death rate of the whole of Victoria, and that of the three principal cities. There is a gradual but definite decrease for Victoria and the metropolis, but at Ballarat and Bendigo, the two big mining centres, such is not the case to any extent. The efforts at eradicating tuberculosis have so far been expended mainly in Melbourne, and the success is most encouraging. The rate for Victoria *in toto* is below that of the cities, from which the evident conclusion is the comparative freedom of the country districts. More than three-fifths of the entire population are in the three cities, so that the remaining two-fifths have a greater influence in lowering the rate than the prevalence in the cities has in raising it. The detrimental influence of quartz mining, though directly acting on a section of the adult males only, is felt by the whole community of the mining centre. Thus the death rate of Bendigo is twice that for Victoria generally. People suffering from chronic chest diseases are attracted to Bendigo by its mild winter season. This, however, is not a great factor in the high consumptive death rate, as the visitors frequently return to their own homes before the final end comes.

The majority of the miners affected die in the prime of life, and Table I. shows the average age year by year to be just under or above 50 years. Allowing a further period of 2½ years as being the time prior to death, during which the men are incapacitated, the real incidence of the disease is determined. The age at death may be seen in more detail from Tables V. and VI., which give the number of miners dying of phthisis (tuberculous) and bronchitis respectively in age groups and for five-year periods. More young men are dying of recent years, and also there are more old men. The average age at death on this account remains fairly constant. Many of the veterans who now are victims to tuberculosis lived on in previous years and succumbed to "natural" causes.

A more comprehensive idea of the age at death is got by looking at Chart F, which gives a graphic representation of the age distribution of the miners who have died of phthisis and bronchitis. Graph FF is constructed from the 891 deaths that took place since 1875 in Bendigo, due to the former disease, while Graph HH represents the 280 from the latter. As stated elsewhere, the latter should be superimposed on the former to give

Table V.

Number of Deaths amongst Bendigo Miners in age groups for five year periods, from January 1875 to June 1906, due to Phthisis (Tuberculous).

Age.	1875-79.	1880-84.	1885-89.	1890-94.	1895-99.	1900-04.	1905-06(½)	Totals.
20—25	2	3	2	4	7	8	1	27
25—30	1	6	3	7	14	7	4	42
30—35	7	3	2	3	5	8	5	33
35—40	11	9	7	8	3	13	10	61
40—45	15	12	12	10	14	18	9	90
45—50	26	24	24	13	22	19	5	133
50—55	11	22	32	21	32	23	12	153
55—60	5	11	18	31	31	29	10	135
60—65	7	10	14	30	37	31	7	136
65—70	0	3	6	12	16	23	3	63
Over 70	0	1	0	1	6	5	5	18
Totals	85	104	120	140	187	184	71	891

Table VI.

Number of Deaths amongst Bendigo Miners in age groups for five year periods, from January 1875 to June 1906, due to Chronic Bronchitis.

Age.	1875-79.	1880-84.	1885-89.	1890-94	1895-99.	1900-04.	1905-06(½)	Totals.
20—25	—	—	—	1	—	—	—	1
25—30	—	—	—	1	1	—	—	2
30—35	—	—	1	1	—	—	—	2
35—40	1	—	—	—	1	2	1	5
40—45	2	3	—	—	1	3	1	10
45—50	—	5	10	4	2	—	5	26
50—55	3	3	10	3	7	3	2	31
55—60	1	4	17	23	15	7	1	68
60—65	2	7	9	14	17	11	6	66
65—70	2	2	7	7	16	9	2	45
Over 70	3	—	5	3	5	7	1	24
Totals	14	24	59	57	65	42	19	280

Table VII.

Number of Deaths due to Phthisis amongst Adult Males other than Miners Living in Bendigo, in Age Groups, and for 5-year periods from January 1875 to June 1906.

Age.	1875-79.	1880-84.	1885-89.	1890-94.	1895-99.	1900-04.	1905-06(½)	Totals.
20—25	13	30	34	37	26	18	2	160
25—30	12	21	28	31	23	21	6	142
30—35	16	14	16	16	26	16	9	113
35—40	7	20	21	16	17	16	3	100
40—45	24	17	12	11	11	15	3	93
45—50	22	23	26	10	15	8	1	105
50—55	20	26	33	9	8	9	4	109
55—60	7	15	18	21	15	6	1	83
60—65	0	11	17	14	13	16	1	72
65—70	1	4	8	16	9	6	2	46
Over 70	0	2	5	13	11	9	2	42
Totals	122	183	218	194	174	140	34	1,065

Similar Table as above of Adult Female Deaths.

Mortality from Phthisis and Chronic Bronchitis amongst Bendigo Miners, between January 1875 and June 1906.

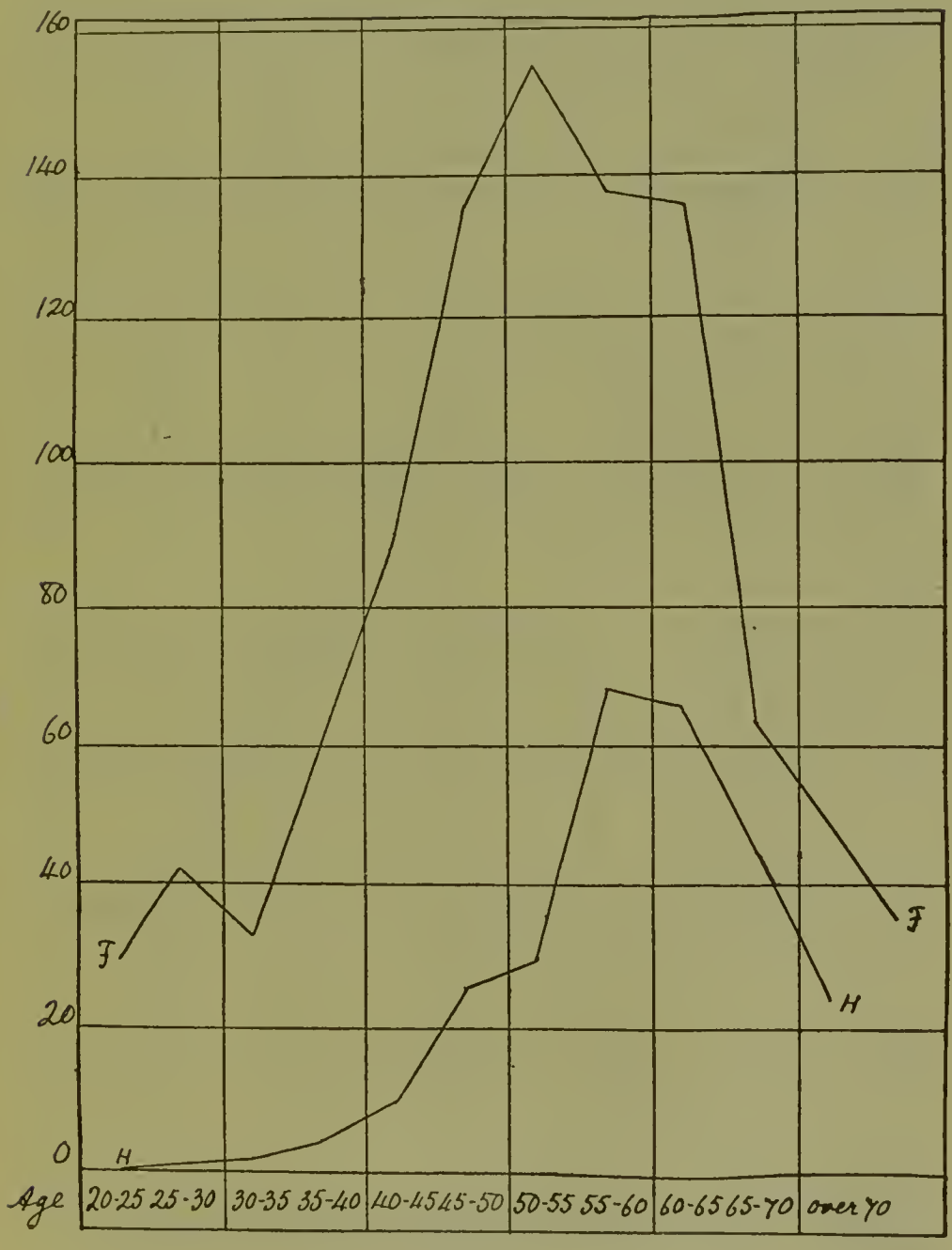


CHART F.

Graph FF shows age distribution in 891 deaths from Phthisis.

Graph HH shows age distribution in 280 deaths from Chronic Bronchitis.

Mortality from Phthisis amongst Adult Males (non-miners), dying in Bendigo, between January 1875 and June 1896.

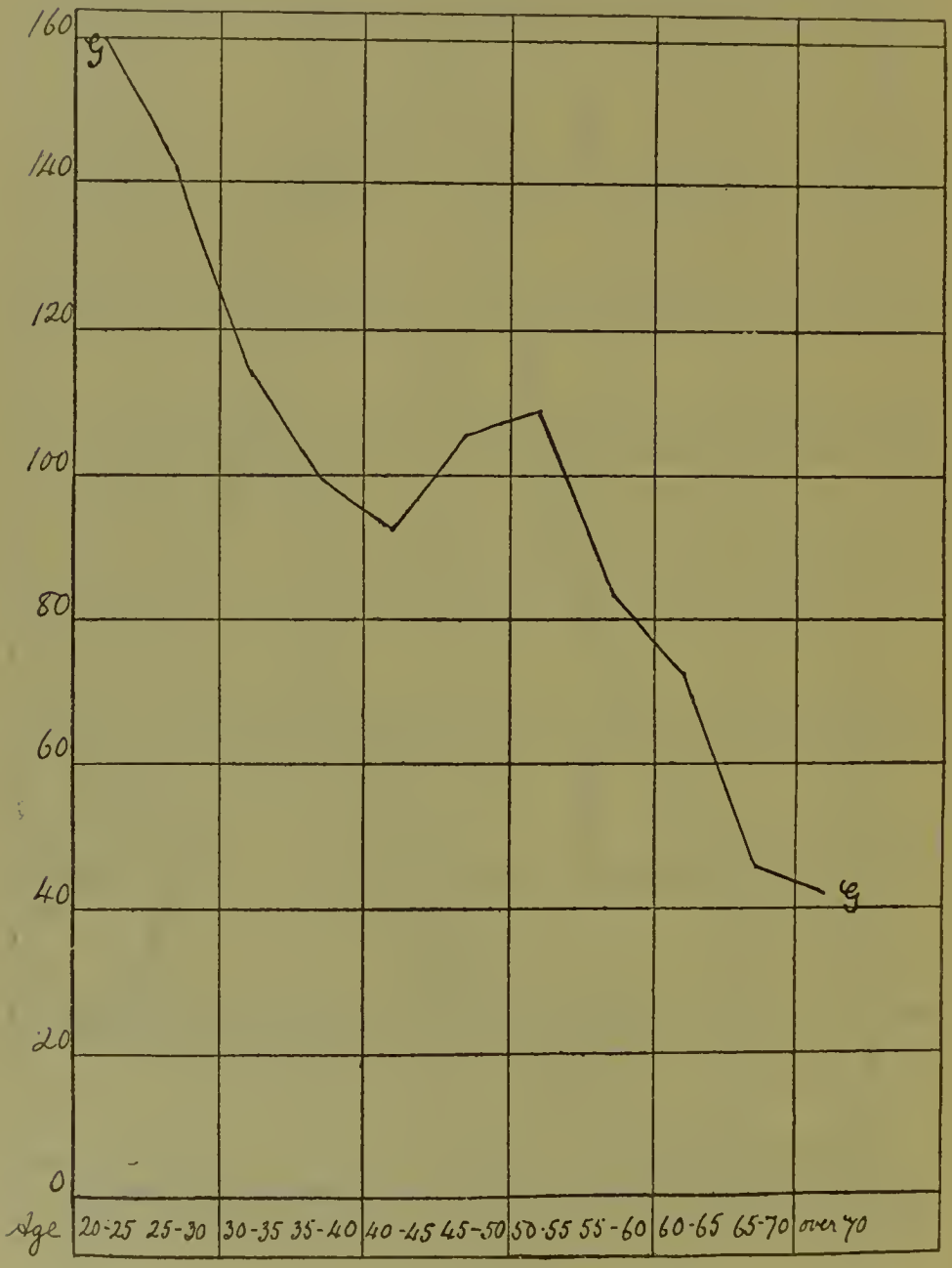
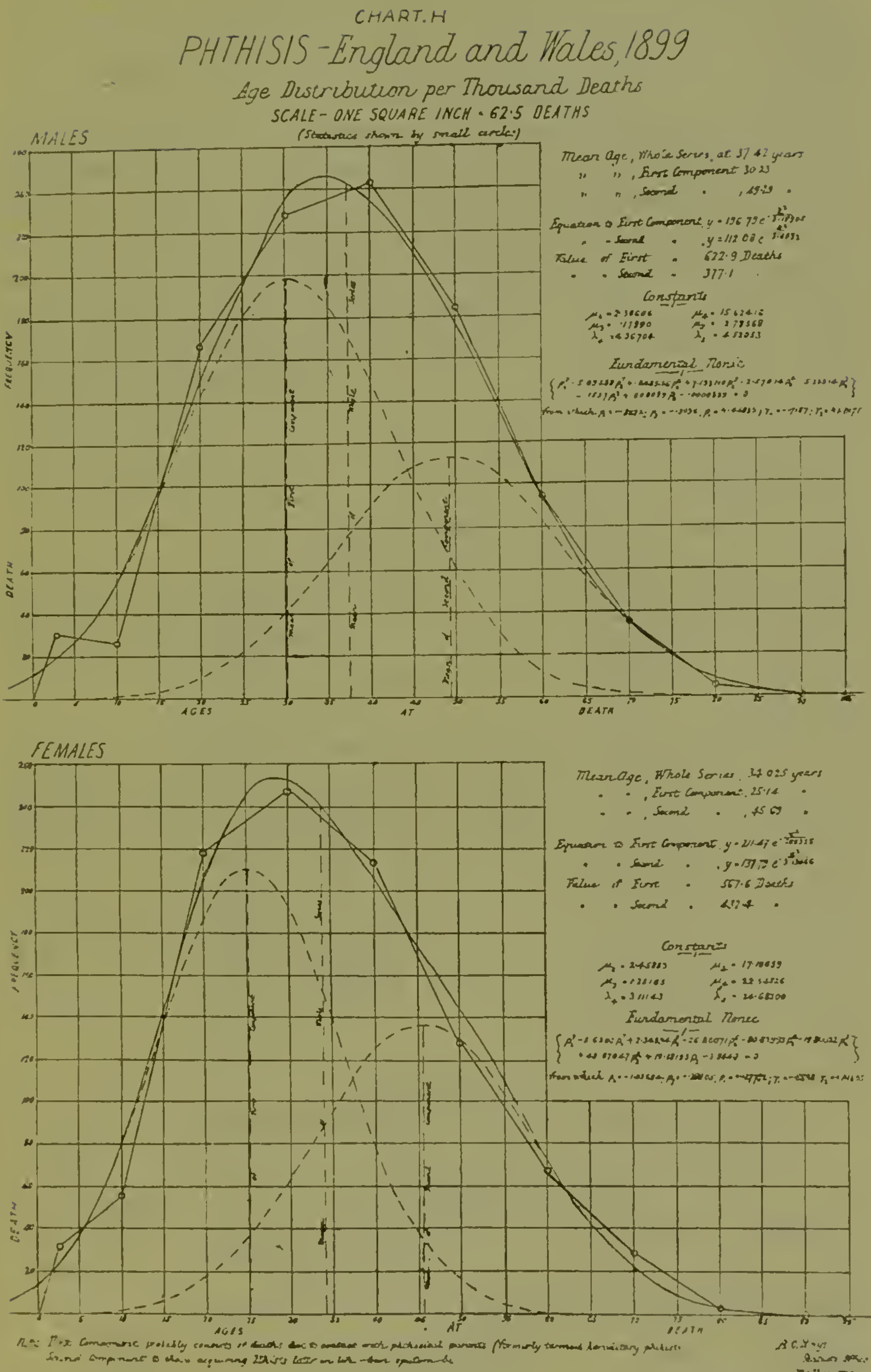


CHART G.

Graph GG shows age distribution in 1,065 deaths.



* This Chart is published with the courteous permission of Mr. A. O. Powys, of the Statist Office, Melbourne, who prepared it.

the more accurate representation of tuberculosis of the lungs amongst the miners. Graph GG is composed from the 1065 deaths from phthisis that have occurred in Bendigo since 1875 amongst non-mining adult males.

Every curve showing the age distribution from phthisis may, by a nonic algebraic equation, be split into two component curves, one having its mean age some years younger than the second, as shown by Chart H. These represent more or less accurately the cases in which hereditary factors or environment, especially occupation, respectively play the major part in predisposing to the bacillary infection. Thus in Chart G the small upward break from 40 years onwards is what might be termed the occupation rise, and is trifling in comparison with the early mortality amongst non-miners. Whereas the reverse obtains amongst quartz miners. Chart F shows the occupation curve greatly increased, and the early mortality is insignificant when compared with the latter. These charts strikingly bring out the important influence the mining occupation has on the health of its followers. It may be safely assumed that the other environment factors in the case of each body of men—miners and non-miners—differ but slightly.

No occupation statistics are available in Victoria to compare with the death rate amongst the miners, but below is the mortality from lung diseases amongst three groups of miners, and also amongst occupied males in England and Wales. These are taken from a report on the prevalence of miners' phthisis in Cornwall by Dr. Haldane. The corresponding mortalities are given also for the Bendigo miners and for adult males throughout Victoria.

TABLE VII.

Comparative Mortalities from Respiratory Diseases per 10,000 living.

			Rate
Adult Males Victoria, 1903-05 ..	Phthisis	20·8	
	Pneumonia	12·1	
	Other respiratory diseases. ..	10·0	
	Total	——	42·9
Occupied Males England and Wales 1890-92			58·0
Bendigo Miners 1905-06 ..	Phthisis	129·6	
	Pneumonia	27·4	
	Bronchitis	34·6	
	Total	——	191·6
Tin Miners Cornwall 1900-02			182·0
Coal Miners (Eng.) 1890-92			58·0
Ironstone Miners (Eng.) 1890-92			46·0

The mortality from lung diseases of the quartz miners at Bendigo and that of the tin miners of Cornwall are far in excess.

The workings of both classes of mines are similar, and differ from the methods of coal and ironstone mining.

From the foregoing charts and tables, the great mortality amongst Bendigo miners is seen, and this is due to respiratory diseases, notably tuberculosis. Many of the affected men are young or in the prime of life and vigour. The number of fatal mining accidents is rapidly diminishing, indicating the improvements that are being made in the safety appliances and machinery. The increasing mortality from disease makes it clear that the same care is not taken of the miner's health. Not only is the mining class affected, but from them infection spreads to the whole community.

TABLE IX.

Mortality Table for Bendigo Miners from January 1875 *to June* 1906.

BENDIGO CITY (EXCLUSIVE OF EAGLEHAWK).				
Pulmonary Disease.	Phthisis (tuberculous)	661		
	Bronchitis	230	1,065	
	Pneumonia	174		
Non-pulmonary Disease.	Cardiac Disease	176		
	Senility and Asthenia	142		
	Abdominal Disease	86		
	Cancer	76		
	Nervous Disease	66		
	Typhoid Fever	64		
	Vascular Diseases	39	754	
	Renal Disease	37		
	Diseases of Urinary Tracts	15		
	Septic Infections	15		
	Rheumatism	6		
	Hydatids	4		
	Alcoholism	3		
	Other Diseases	25		
Violent Deaths.	Fatal Mining Accidents	193		
	Other Accidents	41	249	
	Suicides	15		
	Total			2,068
EAGLEHAWK.				
Pulmonary Disease.	Phthisis (tuberculous)	240		
	Bronchitis	50	347	
	Pneumonia	57		
Non-pulmonary	Inclusive of Accidental Deaths other than those caused by Mining		316	
	Fatal Mining Accidents		87	
	Total			750
	Grand Total for District			2,818

SYMPTOMS.

The clinical facts are gathered from personal examination of 192 cases. These embrace all stages of the disease. Some of the men were still employed underground; others, though unable to work continuously, did so at intervals. Others, again, were confined to bed, and these were examined, some in the Bendigo Hospital, but the majority of cases in their own homes. From

my frequent visits to their dwellings, a good insight was obtained into the home conditions existing amongst the miners.

The symptoms in all the cases pointed to disease of the respiratory organs. Some patients consulted me with various ailments, which were in no way brought on or aggravated by their occupation. With these cases, on account of the special object of my investigation, I had little to do, and they are not taken into account.

The following cases exemplify in a typical manner the nature and the stages of the various diseases to which the Bendigo miners are peculiarly liable. Those in the earlier stages are placed first, and the more advanced further on in the series.

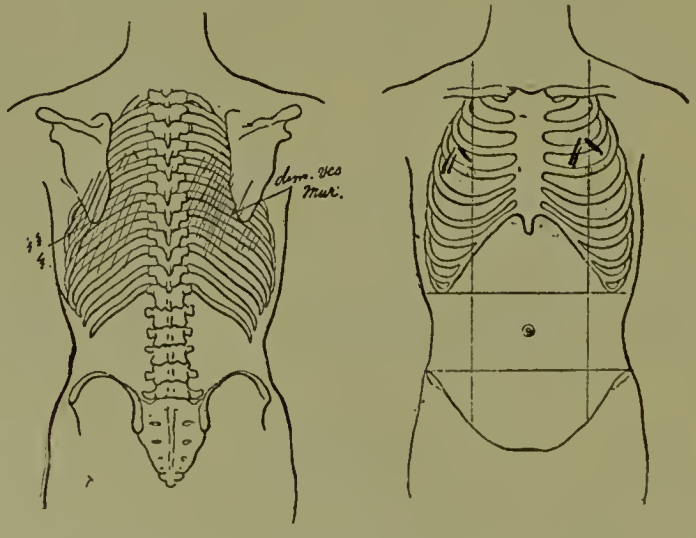
NON-TUBERCULOUS CASES.

Wm. P., æt. 44. Examined 7th March, 1906.

Mining about 12 years, with short spells above ground. Patient is spare, but not losing weight.

Pain in left side lasted four days. Slight cough, with little expectoration at present, but has had frequent coughs since he took to work underground. Says he had "rheumatism" in shoulder once while working with the rock drill. The cold, exhaust air played continuously on the one part, and to this cause also he assigns the pleurisy.

Family history good.



Physical examination gave the signs of acute dry pleurisy in left side, and of old adhesive pleurisy on the right. Respiration, 26; pulse, 80; temp., 98·6°.

Chest expansion, 33 to 34½ inches.

Sputum contains no tubercle bacilli.

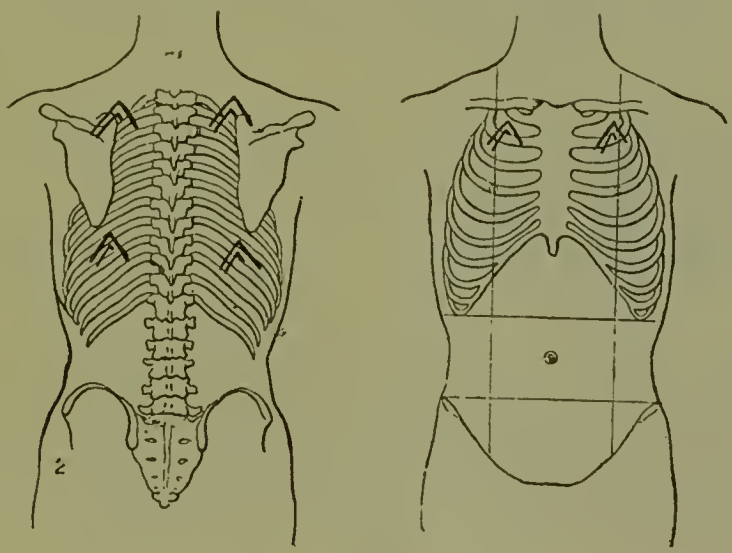
T. F., æt. 50. Examined 16th February, 1906.

Mining seven years, then was engine driver on the surface for 20 years. Lately has been "underground boss" for eight years, working in some dusty places. He has not worked for 12 months.

Patient is a florid, stout man, looking the picture of health. Five years ago he first noticed he was short of breath on exertion. There is no bodily weakness, and no languor.

Appetite good; bowels normal. Not much cough, with but little expectoration. No hæmoptysis; no pleurisy or pneumonia; no rheumatism.

One brother out of seven died of phthisis. Family history otherwise good.



Physical examination gave only slight general prolongation of expiration. Respiration, 18; pulse, 84; temp., 97·8°.

Chest expansion 38 to 40 inches.

Opsonic index to tubercle bacilli is 1 (normal).

Blood examination—smear normal. Erythrocytes, 5,600,000; hæmoglobin, 105%; leucocytes, 8000 per c.m m.

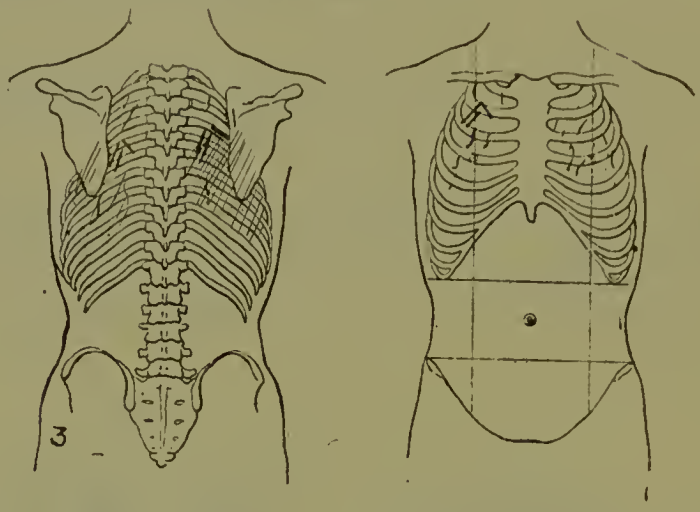
T. H., æt. 58. Examined May 29, 1906.

Mining for 25 years. For last 12 years has been ailing, and for 8 years has not worked at all. Patient is spare, but looks healthy.

Frequent coughs at the beginning of illness, but no dyspnœa till 5 years ago. Now, for the last 12 months, the slightest exertion brings on breathlessness. Used to have severe pains in both sides, so much so that he would hardly be able to move the arms. No expectoration at present.

General health good. Much gastro-enteritis 12 months ago, and then felt very tired; but he has felt well since. Respirations, 20; pulse, 76; temp., 98·2°.

Family history—No tuberculosis.



Physical examination gave evidence of bronchitis, emphysema, and pleurisy.

Opsonic index, as regards tubercle bacilli, is 1·01. No night sweats; no hæmoptysis.

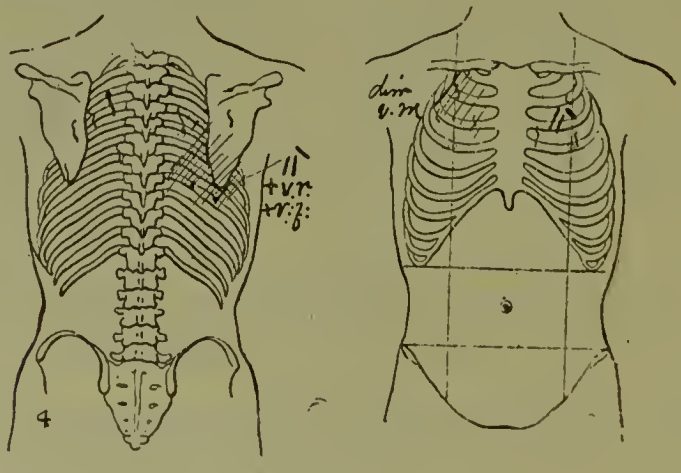
Urine, 1022; no albumen or sugar.

J. H., æt. 51. Examined 21st March, 1906.

Mining continuously for 30 years. Started work underground when 12 years of age. Subject to colds for last 15 years, and to shortness of breath for 10 years. No pleurisy or pneumonia, but a fair amount of pains in limbs.

At present time has been ill for 4 weeks with an attack of bronchitis. Not losing weight. No hæmoptysis. Appetite and digestion good.

Family history—No consumption.



On examination, there were stridor and wheezing. Respirations, 30; pulse, 88; temp., 98·2°. Rhonchi and prolonged expiration in chest. Sputum does not contain tubercle bacilli.

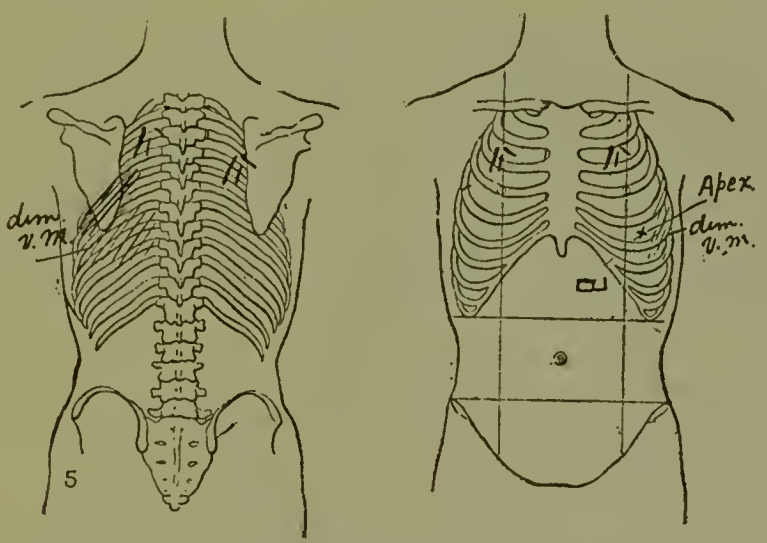
J. S., æt. 46. Examined 13th February, 1906.

Commenced mining æt. 18. Left off work below 8 years ago, as his health was failing. Has since done light work on the surface. He was underground 20 years.

Shortness of breath came on one year prior to ceasing mining, and he has been troubled ever since, especially if there is any bronchial catarrh, and lately the dyspnœa is becoming extreme.

About 8 months ago had a very severe attack of bronchitis, and now only a little expectoration in the morning, with an irritable cough.

Pneumonia 4 years ago, but says never had pleurisy. Has lost 10lbs. in weight within the last year, and also feels weaker. General health otherwise good. Father died, æt. 58, of "miner's complaint," in Bendigo. Family history otherwise good.



Physical examination gave the signs of emphysema and some old left basal pleurisy. Chest expansion, 30 to 32 inches. Respirations, 22; pulse, 84; temp., 98°.

The fluorescent screen showed irregular shadows and lighter areas, with a dark line marking out the right interlobar fissure, and immobility of the right vault of the diaphragm.

Sputum contained no tubercle bacilli.

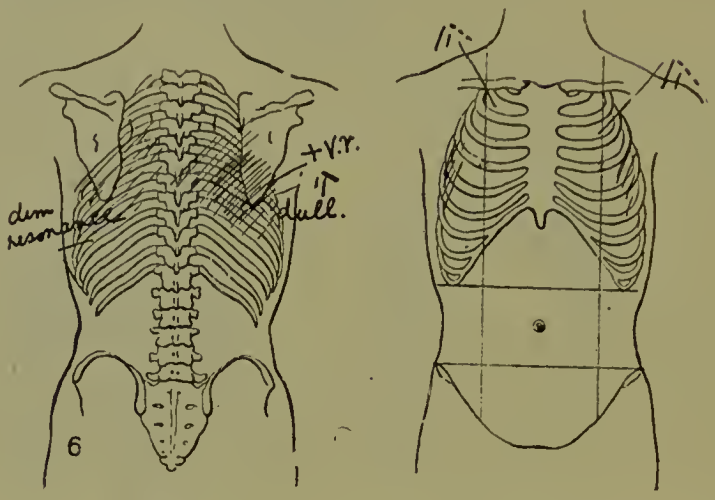
J. P., æt. 57. Examined 24th January, 1906.

Mining first at age of 15, and worked continuously below till five months ago. Shortness of breath was the immediate cause of his ceasing work. Some dyspnœa on exertion existed for 18 months prior to that.

Patient had, when working, a lot of coughs, with blackish muco-purulent expectoration. No pleurisy or pneumonia. No hæmoptysis.

Appetite is poor, and he suffers greatly from bad digestion. Bowels costive. Moderate drinker.

Family history—No tuberculosis.



Physical examination gave a chest expansion of from 34 to 35½ inches. Respirations, 28; pulse, 108. Vesicular murmur was irregular, and expiration prolonged. Scattered rhonchi and dulness on percussion at both bases posteriorly.

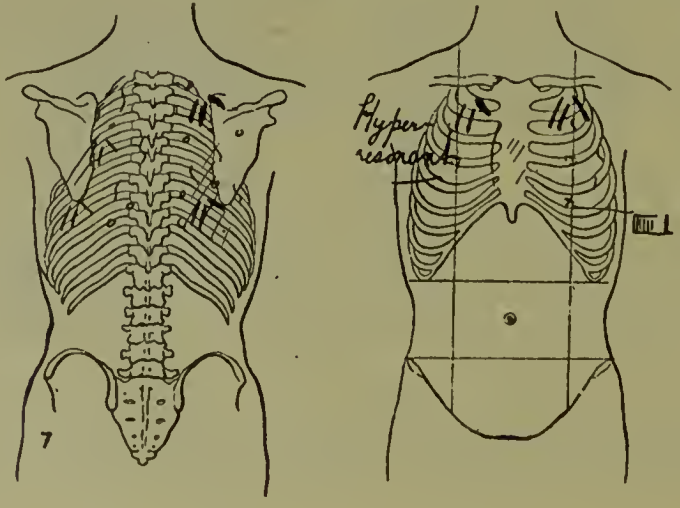
Sputum did not contain tubercle bacilli.

Blood examination showed no abnormal cell elements. Hæmoglobin, 108%; erythrocytes, 5,450,000; and leucocytes, 12,500 per c.mm.

Opsonic index to tubercle bacillus, 1·1.

J. W., æt. 58. Examined 30th January, 1906.

Started mining in Cornwall when aged 10 years. Came to Bendigo when aged 25, and has been unable to work during the last 12 years on account of weakness and shortness of breath. Also, has suffered from much pains in the sides. He was subject to coughs for many years prior to ceasing work, and had much expectoration. No hæmoptysis. No pneumonia. Appetite good; patient not emaciated.



Urine, sp. gr. 1012, acid; no albumen or sugar.

Examination gave signs of an acute bronchitis and emphysema.

Chest expansion, 34 to 36 inches.

Temperature varies from 97·6° to 101·6°. Respirations, 26; pulse, 92.

Sputum did not contain tubercle bacilli, and tuberculin test gave a negative result.

Opsonic index to tubercle bacillus, ·88.

Blood examination—Smear normal. Hæmoglobin, 90%; erythrocytes, 5,6co,ooo; leucocytes, 13,680 per c.mm.

Family history good.

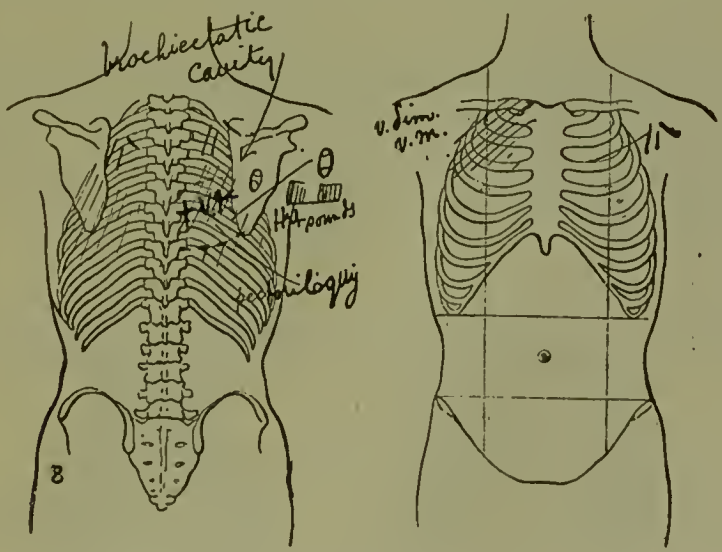
About 4 years ago he developed a right inguinal hernia, probably brought about by the constant coughing.

J. T., æt. 50. Examined 6th February, 1906.

Started mining æt. 24. Has not worked for the last six months. He first noticed shortness of breath six years ago, but it has become much worse the last couple of years. No pleurisy or pneumonia. No hæmoptysis.

He has been subject to colds for many years. Latterly, he has been perspiring freely, and has been feeling weaker. Patient is high coloured, and is well nourished. He has not been sleeping well on account of aching pains in the legs.

Urine, 1015, contains small amount albumen, but no sugar.



Examination showed far advanced emphysema and much old pleurisy. He had marked stridor in breathing. Respirations, 28; pulse, 112.

Blood film normal. Erythrocytes, 5,500,000; hæmoglobin, 105%; leucocytes, 12,200 per c.mm.

No tubercle bacilli in sputum.

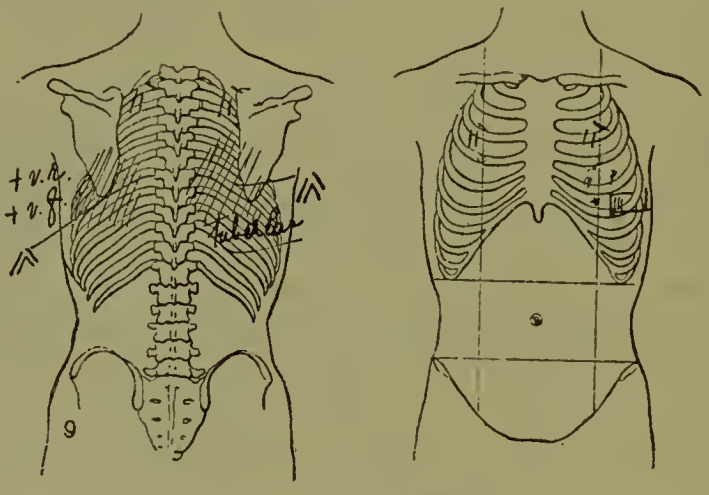
Family history—Father died of heart disease; one brother of "miner's complaint." Rest alive and healthy.

Wm. G., æt. 51. Examined 8th February, 1906.

Started mining æt 15, and worked underground for 18 years. After that he worked as a carpenter, but has done nothing for 9 years. He had an attack of pneumonia 10 years ago, and since then has gradually become worse.

At present he has little cough, but no expectoration. Never any hæmoptysis. Lately he has lost over 2 stone in weight, and has much asthenia. Occasional night sweats. Appetite is moderate and digestion fair.

Family history—Father died of inflammation of the lungs (he was a miner). Two brothers died of "miner's complaint."



Examination showed marked emphysematous changes, with stridor in breathing. Towards both bases posteriorly there was almost consolidation of the lungs. Chest expansion, 35 to 36½ inches.

Urine, sp. gr. 1020; no albumen or sugar.

Blood smear was normal. Hæmoglobin, 95%; erythrocytes, 4,000,000; leucocytes, 11,250.

There was no sputum for examination, but the history and symptoms were suggestive of a chronic tuberculous infection.

Wm. G., æt. 47. Examined 11th January, 1906.

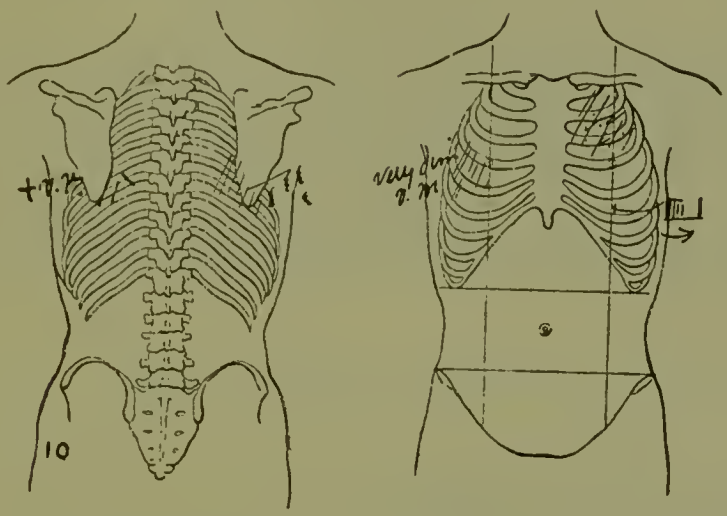
Worked underground for 34 years; commenced at age of 12. Has not been able to work for 12 months. First worked in a coal mine.

Cough off and on for 9 years, and great dyspnœa for some years. Occasional pains in sides, and lately has sweats on the least exertion, and sometimes during the night.

Appetite is poor, and he has lost one stone in weight since ceasing work.

Cough is very severe first thing in the morning. Muco-purulent expectoration, but it does not contain tubercle bacilli. No hæmoptysis.

Urine, 1018; no albumen or sugar.



Physical examination showed chest expansion to be from 33½ to 35 inches. Respirations, 18; pulse, 84; temp., 98°. Signs of emphysema and pleurisy in lungs. Vesicular murmur raised in pitch, and vocal resonance much increased at the left base.

Family history—Two brothers (miners) died of asthma and heart disease, and one sister of "chest trouble."

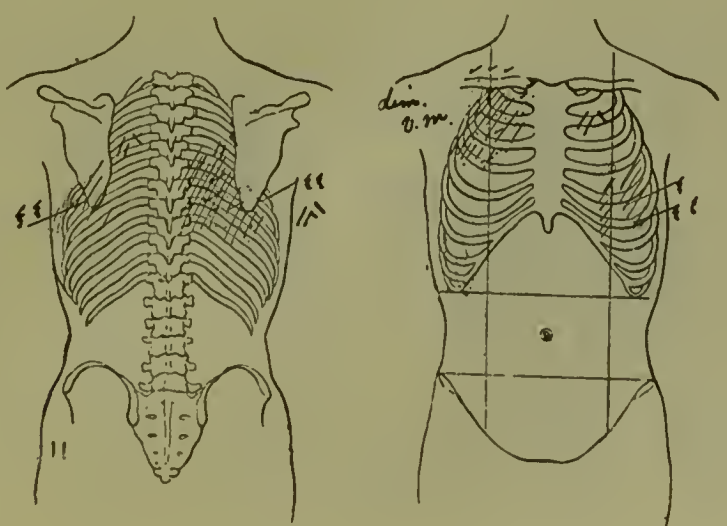
Opsonic index to tubercle bacilli, 1·01.

TUBERCULOUS CASES.

A. E., æt. 33. Examined 24th April, 1906.

Mining 13 years. Worked last 12 days ago.

Ailing six months with pain in chest, weakness, and loss of appetite. Vomiting lately. Bowels costive. He has lost over two stone in weight within last three months. Frequently he has sweats at night, and also perspires easily during the day. Much cough, with muco-purulent expectoration. No hæmoptysis. For last three years he has been subject to coughs, but has been able to work all the time. Sputum contains numerous tubercle bacilli.



For the last year he has worked at a depth of 4200 feet (temp. of air, 95°; humidity saturated; and percentage of CO_2 is ·203); prior to this he worked in an extremely dusty mine for 15 months.

Father and mother alive and well. Family history good.

Examination of lungs showed recent pleurisy at both bases, and at right apex and base there was evidence of consolidated and breaking-down lung. Pulse, 96; respiration, 24; temp., 99·4°.

Blood examination showed anæmia of a secondary type. Hæmoglobin, 75%; erythrocytes, 4,450,000; leucocytes, 21,400 per c.mm.

W. A., æt. 32. Examined 9th January, 1906.

Started mining æt. 13 in a coal mine at Newcastle, N.S.W. He came to Bendigo 13 years ago, and worked below up till 18 months ago, when ill-health compelled him to cease work. Prior to this he had pleurisy twice, also a constant cough, but no expectoration.

Patient is emaciated looking, sallow, and face pigmented.

Now he has profuse muco-purulent expectoration, and much night sweating. Sputum was blood-tinged a week ago, but he has not had any hæmoptysis. At times the sputum is bluish black in color.

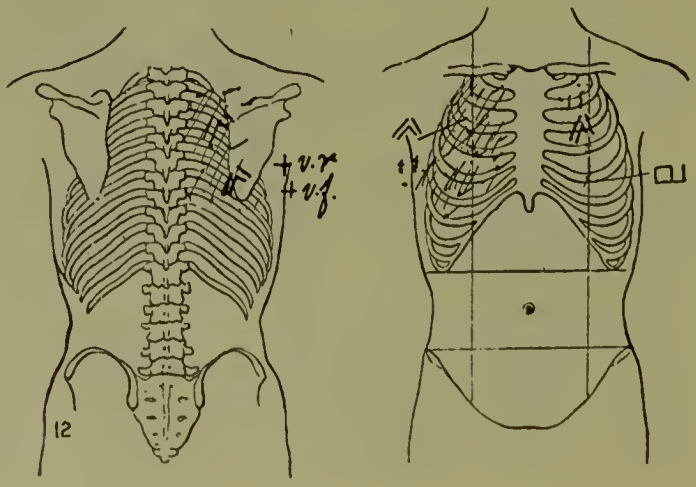
For two years there has been great dyspnœa on exertion.

He has lost two stone in weight since leaving off work. Vomits occasionally. Much flatulent indigestion. Bowels regular; heart and other organs apparently normal.

Urine, sp. gr. 1018; no albumen or sugar,

Family history and previous health good.

Sputum contains numerous tubercle bacilli. Opsonic index is ·74.



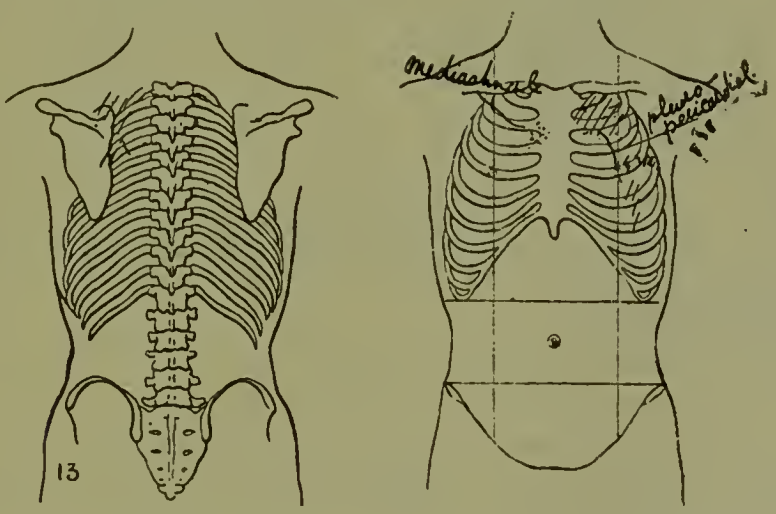
Examination of chest showed crepitations and other catarrhal signs at both apices, and nearly all over the right side with tubular breathing and increased vocal resonance and fremitus.

J. P., æt. 25. Examined 9th January, 1906.

Worked underground eight years. Has not worked for five months from ill-health. As far as he can remember, he has had a cough from the time he commenced mining. His actual illness started five months ago with left-sided pleurisy, which was so severe as to make him take to bed.

Much muco-purulent expectoration, which is blood-streaked at times. Never any hæmoptysis. Sputum contains numerous tubercle bacilli.

Lost much weight, and suffers greatly from gastro-intestinal disturbances.



Other organs healthy as far as could be determined.

Examination of lungs showed consolidation and breaking-down at left apex, and some pleuro-pericarditis as well.

Family history—Father died of miner's complaint five years ago, æt. 51.

N.B.—Would this man have become tuberculous whatever his occupation may have been? Was the onset hastened by the detrimental results of the work below ground?

R. A., æt. 24. Examined 25th January, 1906.

Mining eight years. Ceased work eight months ago. Has worked in some very hot, dusty places, and been subject to coughs for some years. Now the dyspnœa is extreme, with profuse sweating.

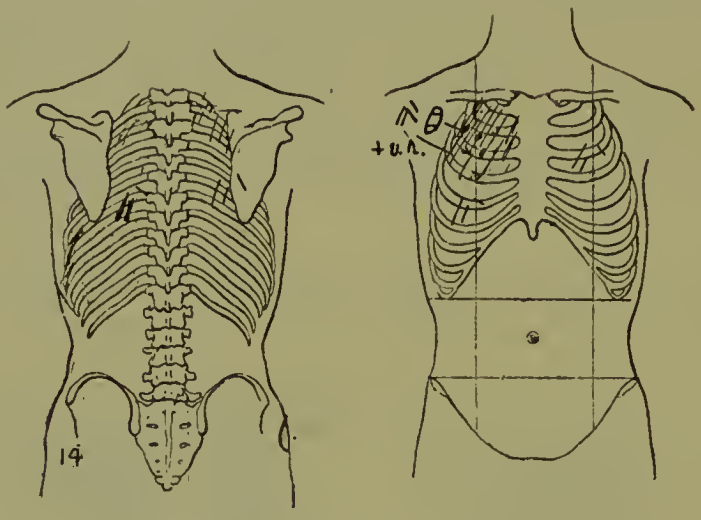
Symptoms were present for 18 months before ceasing work.

Much cough, with blackish muco-purulent expectoration. There are occasional streaks of blood in sputum.

Never any pneumonia, but pleurisy frequently. He used to be strong and robust. Weakness is now extreme. Appetite poor, and he has lost a lot in weight. No alcohol.

Urine, sp. gr. 1018,; no albumen or sugar.

Examination—Respiration, 26; pulse, 140; temp., 99·6°.



Much emaciation. Brown pigmentation of face marked. Signs of a cavity at right apex, and of emphysema throughout rest of lung.

Family history good.

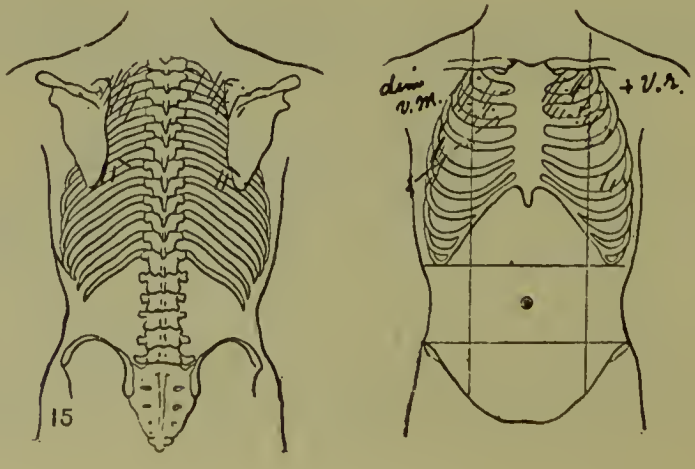
Opsonic index to tubercle bacillus, ·62.

F. A., æt. 44. Examined 22nd March, 1906.

Started mining æt. 19. Underground continuously up till 18 months ago, when he was compelled to cease work from cough and weakness.

Dyspnœa came on about the same time rather rapidly. Much expectoration, mostly muco-purulent, but blackish at times.

Never any pneumonia, but complained of stitches in the sides for years. Hoarseness for some time.



Family history good, but he lived in a house in which two people had died of tuberculosis.

Examination.—Signs of breaking-down lung at both apices. Elsewhere there was marked emphysematous changes. Heart normal; chest expansion from 33 to 34 inches. Urine, 1012; albumen, no sugar. Respiration, 24; pulse, 92; temp., 99°. Sputum contains numerous tubercle bacilli. Opsonic index, ·8.

Blood examination showed no abnormal cells. Hæmoglobin, 75%; erythrocytes, 4,900,000; leucocytes, 10,400.

C. R., æt. 59. Examined 2nd February, 1906.

Started mining æt. 18. He worked underground continuously till 19 years ago, when he was appointed manager. He is still manager, going below frequently.

He has had shortness of breath on the least exertion for over 12 years, but much worse now, and for the last seven years has felt it severely.

Little cough till lately. Now he coughs much, with muco-purulent expectoration, which contains numerous tubercle bacilli.

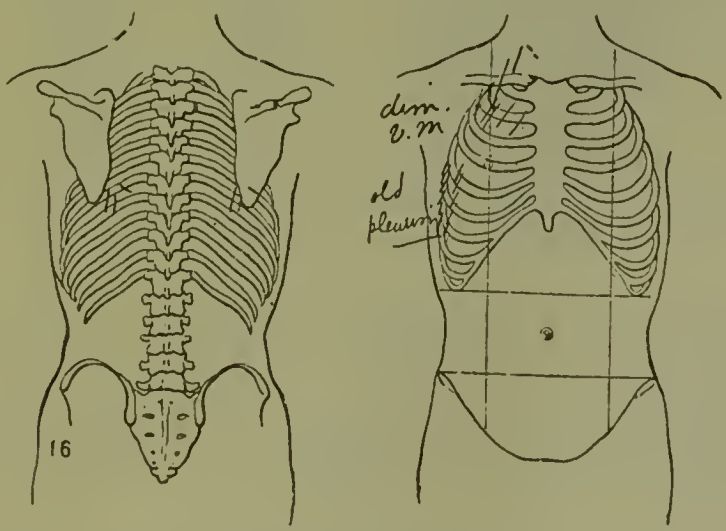
Never any pleurisy or pneumonia.

No hæmoptysis. No night sweats.

Heart—A.B. in 5th space within the nipple line. Sounds normal. Patient says his feet swell occasionally. Pulse, 88, and good volume.

Health has been good till lately. Now he has some flatulent indigestion, and is losing weight.

Urine, 1023; no albumen or sugar.



Examination of chest revealed an expansion from 38 to 40½ inches. Chest is well developed, and the physical signs only consist in prolonged expiration and wheeziness in places. No adventitiæ. Towards the bases there is increased vocal resonance and vocal fremitus. Respiration, 36; temp., 99°.

Family history good.

Patient went away for a change for four months to a mountainous climate. He very much improved in health, but the dyspnœa remained the same.

Opsonic index to the tubercle bacillus, ·63.

Blood examination showed 5,025,000 erythrocytes, 22,600 leucytes; hæmoglobin, 80%. Smear showed no abnormal cells.

A. G. C., æt. 42. Examined 13th February, 1906.

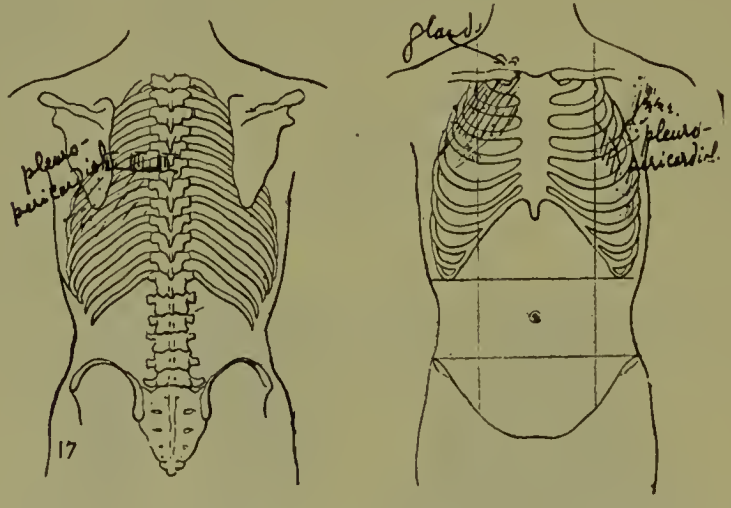
Mining since æt. 21 till six months ago. Working continuously for 20 years.

Shortness of breath came on suddenly, and causesd him to cease work. His general health, at the same time, began to fail. He has a severe cough, and lately has been spitting much phlegm, which contains numerous tubercle bacilli.

Spat up about one ounce of blood 3 weeks ago, and had a severe attack of pleurisy at some time. Never had any pneumonia or other illness.

Appetite fair; digestion and bowels normal. Night sweats at times. Lost 8lbs. in weight.

Family history good.



Examination showed advanced tuberculous disease at right apex and left base. Respirations, 40; temp., 101·6°; pulse, 120. Heart normal.

Died rather suddenly, with signs of heart failure, on 21st May, 1906. Autopsy not permitted.

J. K., æt. 50. Examined 16th February, 1906.

Started mining æt. 20, and worked underground continuously almost for 29 years. Subject to cold during this time. Seven months ago he met with an accident, which incapacitated him from work. Shortly afterwards his health began to fail, though

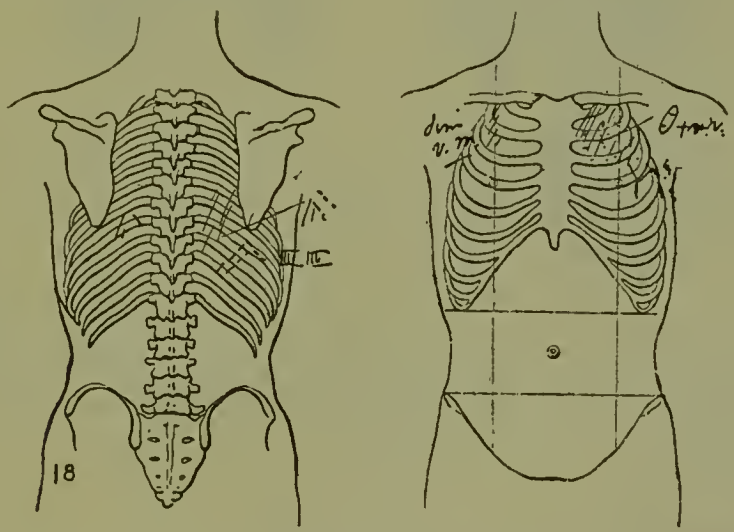
he had suffered from dyspnœa on exertion for many years.

Expectoration is profuse, with small amounts of blood several times. Other times it is black in colour. On examination, numerous tubercle bacilli were found. Lost flesh at onset, but lately has gained slightly in weight. Digestion fair. No urinary trouble.

Urine, 1017; no albumen or sugar. No œdema of extremities.

Sweats occasionally at night and during the day on the slightest exertion.

Family history—Father died of asthma and bronchitis; mother of a wasting disease. One brother of "miners' complaint," and a sister of consumption.



On examination, respirations, 28; pulse, 120; temp., 99°. Chest expanded from 34 to 35 inches only. Lungs gave evidence of emphysema, consolidation and a cavity at left apex; also many moist sounds all over each lung. Posteriorly, inspiration at right base was of an interrupted character.

Opsonic index to tubercle bacillus, ·57.

About 3 months subsequent to examination he died suddenly from hæmoptysis. For autopsy notes see Case (VI.)

H. H., æt. 41. Examined 7th December, 1906.

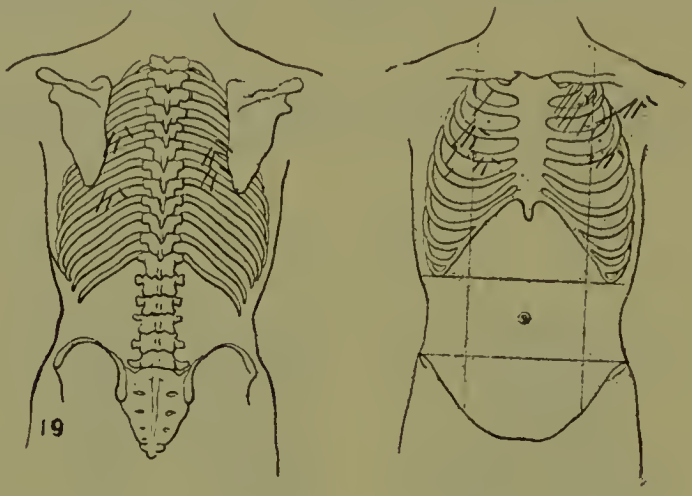
Started mining in a South Australian copper mine, but for 19 years he worked in the Bendigo mines. Has not worked for 2½ years on account of ill-health, which just consisted in dyspnœa on exertion. This started rather abruptly 6 months prior to ceasing work.

Facial aspect anxious. Skin of face much pigmented, and great emaciation of body.

Slight cough only lately, with little muco-purulent expectoration. No hæmoptysis.

Never any pleurisy or pneumonia, and health good when working. Appetite fair. Bowels costive. Lost over 2 stone in weight since onset of symptoms, and now he has much asthenia.

Family history—Father died of "miners' complaint;" mother alive and well. He has 10 children, all strong and healthy.



Examination showed chest expansion from 35½ to 37 inches. Respirations, 24; pulse, 88; temp., 98·2°. Signs of emphysema all over chest, with those of consolidation and breaking down lung superadded at left apex. Heart sounds normal.

Urine, sp. gr. 1018; no albumen nor sugar.

Sputum contains few tubercle bacilli.

Opsonic index to tubercle bacillus, ·54.

Blood examination showed no abnormal cells. Hæmoglobin, 60%; erythrocytes, 3,600,000; leucocytes, 16,250.

Patient died 16th April, 1906. No autopsy.

J. C., æt. 54. Examined 28th December, 1905.

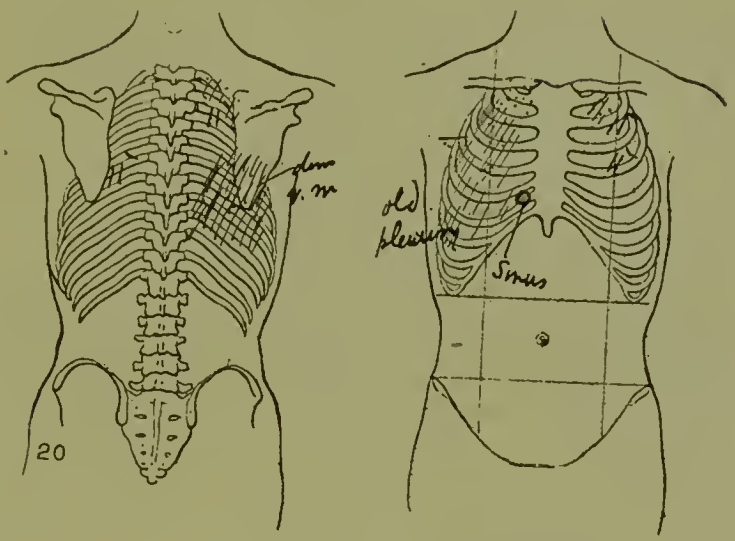
Started mining æt. 23, and ceased work below æt. 46. Has not been able to work for last 8 years at all. Three years prior to ceasing work, he had dyspnœa, with frequent attacks of bronchitis, and felt tired and languid. He has progressively become worse, but especially so the last 6 years. Now weakness and dyspnœa are extreme, and patient is much emaciated. Never any œdema of feet.

Much dyspepsia and loss of weight; much diarrhœa.

Pleuritic pains and coughs frequently. No hæmoptysis. Sputum is now muco-purulent and slate coloured at times, and contains numerous tubercle bacilli.

Nocturnal micturition; no dysuria.

Urine, sp. gr. 1014, trace of albumen; no sugar.



Examination—Tubercular sinus in 5th interspace on right side of sternum (which was subsequently found to extend to the lung). Heart sounds feeble. Lungs—Much prolongation of expiration, and moist sounds over both chests.

Family history—Good.

Transferred from Bendigo Hospital to Austin Hospital, where he died. See autopsy (X.)

The clinical histories of the above and other cases show the disease is most insidious in its onset, and, as a rule, only after years of work do definite symptoms present themselves. By this time, however, damage to the lungs has taken place, and the condition is irremediable. The early symptoms are frequently recurring coughs and mild attacks of bronchitis, in which the ciliated epithelium of the bronchial tubes is destroyed, and thereby greater facilities are afforded for the absorption of the dust particles. The general health is good, or the feelings of malaise so slight as not to interfere with the men's capacity for work. The primary irritating cause continues, and the bronchial tubes are progressively more and more damaged. This condition may last for years, and the only symptoms are those of a frequently recurring or of a continuous bronchitis.

The dust particles inhaled are, for the most part, caught in the mucus of the respiratory passages, and spat out again, giving rise to what is popularly called the "black spit." Even years subsequent to working underground, the expectoration may have at times a bluish black discoloration, especially when there is a caseation and necrosis of the lung tissue. Even with-

out any infection with the tubercle bacillus, the expectoration may be profuse and muco-purulent in character, which, on microscopic examination, is found teeming with staphylococci and many putrefactive organisms. In other instances the dyspnœa may be extreme, but the patient has practically no spit, or some only first thing in the morning.

Sooner or later, however, the miner notices he becomes more readily short of breath than formerly, especially so if he has any bronchitis; and this is characteristic of attacks of bronchitis to which the miners are liable—that they become much more dyspnœic than ordinary patients with bronchitis. The breathlessness increases *pari passu* with the amount of harm done to the lung, till, finally, though constitutionally his health is good, the man is compelled to cease working; and at this stage, even while resting, there is wheezing with prolonged expirations, while on the slightest exertion there are marked stridor and hurried breathing. This dyspnœa is unassociated with any signs of cardiac incompetence, and, therefore, is purely respiratory. In no case was the interference with respiration so extreme as to cause cyanosis.

Such is the history of a case of pure fibrosis. The general health may be in every way satisfactory, digestion good, sleep sound, and there is freedom from pain. A few of these cases, with enforced rest on the surface, become the very picture of health, but are unfit for any occupation necessitating the slightest exertion. These give a high percentage of hæmoglobin, with increase in the number of red corpuscles. Others, again, become subject to asthmatical and continued bronchitic attacks, and rapidly become fit for infection by the ubiquitous tubercle bacillus. Even at rest the dyspnœa may continue, with stridor and prolonged expiration; but on auscultation of the chest there is absence of the loud wheezing and sibilant rhonchi heard in typical asthmatic attacks.

Associated with the frequently recurring bronchitic attacks, the men complain of flitting pleuritic pains—"stitches in the side," as they term them. These pains may last from a few hours to a few days, or may be so severe as to confine the patient to bed. Some few cases examined gave a history of fluid being withdrawn from the chest, and one case was admitted to the Bendigo Hospital with extensive bilateral pleurisy with effusion. Rarely, however, was a case moderately advanced examined without finding evidence of old or present pleurisy, as a rule of the dry chronic type. Notably was this the case in the region of the 5th and 6th ribs in the axillary regions. Here, also, where the parietal pleura is nearest the root of the lung and

where the interlobar septum comes to the surface, the early pleuritic rubs are heard.

Upon physical examination, the breathing may be hurried, but more commonly there is simply prolongation of expiration. On the slightest exertion, however, the breathing is distressed, and, occasionally, the facial aspect anxious; but no case presented any cyanosis until in the final stages, when there was a tuberculous infection, and the heart was commencing to fail.

On inspection, diminished chest expansion was evident. There seemed to be no greater proportion of malformed chests than is to be found amongst the average adult male—many being broad shouldered and deep chested, but, in a few cases, there was a tendency to be "barrel-shaped." In accordance with this, none of the lungs examined were of the large lunged emphysematous type, but there was much coarse emphysema in normal sized or contracted lungs. Mensuration showed the average expansion in 30 cases to be 1½ inches, 1 inch or less being all some patients could manage. Frequently an inspiratory drawing in of the intercostal spaces was noted, especially towards the bases, often bilateral.

Percussion showed scattered areas of impaired resonance. This dulness being often towards the bases, and in the axillary regions, was considered partly due to thickening of the pleural with adhesions, and partly to fibroid lung changes. In some cases from fibroid contractions, the area of superficial cardiac dulness was enlarged, and the heart drawn out of its normal position. Increase in tactile fremitus over the lungs was common, but localised diminution not infrequent.

By auscultation, however, the greatest knowledge was gained of the lung condition. The usual evidence of bronchitis, emphysema, and fibroid lung was universal, and, prior to the full development of these conditions, much alteration in the respiratory murmurs was noted, as diminution, prolongation of expiration, raised pitch, and different grades of bronchial breathing. Creaking sounds, perceptible both on inspiration and on expiration, and cardio-respiratory murmurs along the left cardiac border and in the region of the apex beat—notably a series of short puffs synchronous with the heart beat, and equally well heard on expiration as on inspiration, with crackles and fine pleural friction, in this region are common.

Through the courtesy of Dr. Jackson, of Bendigo, I was enabled to examine with the fluorescent screen the chests in three cases of advanced lung fibrosis. Abnormal shadows were present in all, extremely irregular in distribution; but dark lines

in the situation of the interlobar septa stretched outwards from the roots in several, indicating interlobar pleurisy with adhesions. Interspersed between the dark patches were light areas suggesting emphysematous changes in parts of the lungs not so densely fibroid. The dust particles, being chiefly of silica and aluminium, did not increase the density of the shadow thrown by the lung.

Diminished lung expansion was evident, and in all three cases there was impairment on one or both sides in the diaphragm movements; while in one case the right vault was up to the level of the 4th rib, and remained immobile during inspiration. The heart was displaced in two—towards the right in one, and towards the left in the other.

The main symptoms are those of a chronic and obstinate bronchitis. Associated with this condition, sooner or later the lungs become emphysematous. They are not emphysematous in the sense that their area of resonance is increased; often, in fact, it is diminished. There are no distinctive signs by which one can say that this is a miner's lung, but all point to a chronic irritation of the lung and pleuræ, and the results, in addition to being non-remediable, are, to a greater or less extent, steadily progressive.

After what length of time do these symptoms develop? As a rule men, when first taken on, are employed in shovelling and trucking, and it may be some years before the miner is promoted to work with a rock drill. The earlier work involves the inhaling of a certain quantity of dust, but to nothing like the extent that work with a machine in dry country rock does without the beneficial effect of a dust laying water jet or spray. Under these circumstances, a strong, healthy man, going home after his shift with merely a slight cough, may show no detrimental effect to his health for many years. Others, on the contrary, rapidly develop serious symptoms. All men, however, do not become victims. In one mine, for example, two men, aged 67 and 71 years respectively, were found working as mates, and each did a fair day's work. They were not native born, and had not worked altogether in the Bendigo mines.

The length of time elapsing before symptoms manifest themselves in a miner depends mainly on the number of dusty places in which he has worked. In the case of 85 men who had worked only in Bendigo and at mining alone, without spells at employment on the surface, and who had been compelled to give up work altogether on account of ill-health, the number of years working averaged 22.

Associated with the symptoms already given there is little or no constitutional disturbance. The disease is a purely local one of the respiratory organs, and the symptoms point absolutely to these. Though secondary disorders of the heart and other organs are to be expected, such were late accompaniments, and in every instance subsequent to infection with tubercle bacilli, and thus resulted from the combined action of both the fibrosis and the tuberculosis. Sooner or later—very soon in some cases —there is progressive loss of weight and weakness. The appetite diminishes, and there is a feeling of malaise, with acceleration of the pulse rate. The miner notices that he perspires more easily at work below, and also while exerting himself at the surface.

Drenching sweats at night are frequent. The temperature taken at this stage will show a slight rise above normal some time during the 24 hours, and, though a simple bronchitis may produce a febrile reaction, the majority of cases that have a slight evening rise will soon give unmistakable evidence of the tuberculous nature of the illness. The temperature, when taken at regular intervals for a few days, with the patient confined to bed, gives assistance in arriving at the correct diagnosis hardly second to the results of a tuberculin reaction.

The expectoration may be scanty unless there is an associated bronchitis, when it is muco-purulent, with possibly a bluish black tinge. On microscopic examination, if not the first time, with repeated search, a sample of sputum will be found to contain tubercle bacilli.

To the phyiscal signs already given, additional ones may now be found—those of consolidated and breaking-down lung. Then the symptoms progress, and the course is similar to that of pulmonary tuberculosis in a previously undamaged lung, requiring the same mode of treatment. If, prior to this, there have been no signs of pleural involvement, pleuritic signs will now be found, both along the interlobar septa and elsewhere, and this involvement is secondary to lung infection.

The physical signs in some cases, however, were those only of a simple fibrosis, yet examination of their sputum showed bacilli abundant. This emphasises the necessity for examination of the sputum in every case, especially those in which the dyspnœa was extreme.

The symptoms present some slight variations from ordinary phthisis. Hæmoptysis is rare, but in one case it was the final ending (see p.m. No. VI.). This may be understood when it is recognised that the dust irritation sets up a peribronchitis

and a periarteritis at the same time, with the slow production of much fibrous tissue. With excavation of the lung these tough, fibrous cords resist the necrotic process, or they are destroyed so slowly that in nearly all cases the blood is clotted and organised before the vessel wall is destroyed. The dyspnœa is, as would be expected, quite out of all proportion to the tuberculous involvement of the lung. This is even the case when there has been no evident respiratory embarrassment prior to the superadded tuberculous infection. Pneumothorax seems to be extremely uncommon. In many of the chests examined at autopsy it would be an impossible condition, as the pleural cavities were totally obliterated by adhesions.

Many of the advanced cases slept in tents, and were out of doors all the time. The deep brown, sunburnt faces and hands associated with the extreme asthenia, digestive disturbances, and more especially the disability from the advanced grade of dyspnœa, strongly suggested Addison's disease. Whether some were not true instances of this disease as well as the lung complaint it is impossible to state definitely without the evidence obtainable from autopsy.

Table A.

Results of Blood Examination in Fibroid Lung Cases.

Hæmoglobin.	Erythrocytes.	Leucocytes.
108 per cent.	5,700,000 per cubic mm.	8,425 per cubic mm.
105 ,,	5,600,000 ,,	8,000 ,,
110 ,,	5,600,000 ,,	7,860 ,,
105 ,,	5,500,000 ,,	12,200 ,,
108 ,,	5,450,000 ,,	12,500 ,,
100 ,,	5,300,000 ,,	15,800 ,,
100 ,,	5,250,000 ,,	7,250 ,,
95 ,,	5,250,000 ,,	9,435 ,,
90 ,,	5,200,000 ,,	7,250 ,,
104 ,,	5,200,000 ,,	12,500 ,,
108 ,,	5,125,000 ,,	13,200 ,,
95 ,,	5,125,000 ,,	15,235 ,,
90 ,,	5,050,000 ,,	19,600 ,,
105 ,,	5,000,000 ,,	8,650 ,,
85 ,,	4,800,000 ,,	18,435 ,,
95 ,,	4,800,000 ,,	15,900 ,,
90 ,,	4,800,000 ,,	8,435 ,,
95 ,,	4,550,000 ,,	6,875 ,,
80 ,,	4,500,000 ,,	11,325 ,,
95 ,,	4,000,000 ,,	11,050 ,,

TABLE B.

Results of Blood Examination in Tuberculous Fibroid Lung Cases.

Hæmoglobin.	Erythrocytes.	Leucocytes.
80 per cent.	5,025,000 per cubic mm.	22,600 per cubic mm.
80 ,,	4,800,000 ,,	7,280 ,,
65 ,,	4,800,000 ,,	18,090 ,,
75 ,,	4,500,000 ,,	21,400 ,,
80 ,,	4,300,000 ,,	11,060 ,,
65 ,,	4,000,000 ,,	17,500 ,,
70 ,,	3,900,000 ,,	18,650 ,,
60 ,,	3,655,000 ,,	16,250 ,,
70 ,,	3,325,000 ,,	16,000 ,,
65 ,,	3,200,000 ,,	25,500 ,,

Many of the examinations included in Table A were from cases of advanced lung fibrosis, but the patients, though unable, on account of distress in breathing, to do manual labor, looked the very picture of health. This class uniformly gave a high count of red corpuscles, and the increase must be looked upon as an effort to compensate for the interference with the respiratory processes in the lungs. Where, however, the individual was not so robust, or had symptoms of an acute catarrh of the bronchial tubes, no such increase was found, and even in some cases there was a diminution in the number of red corpuscles.

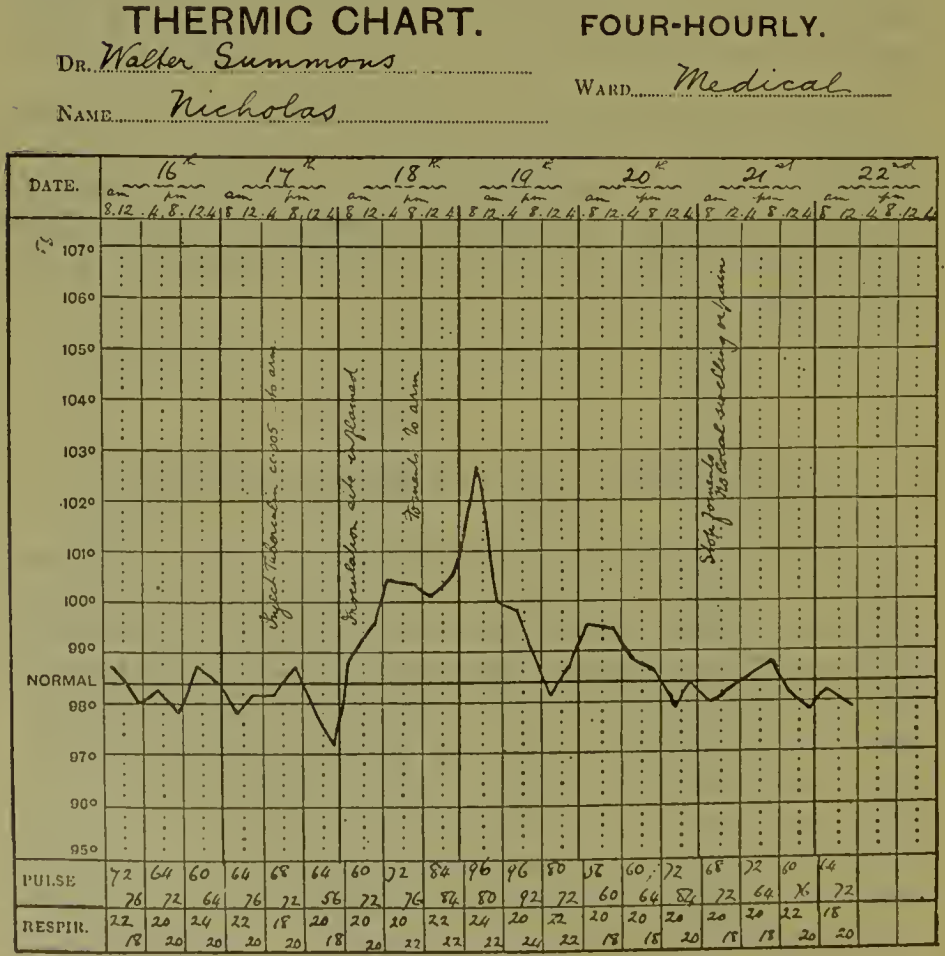
Table B, on the other hand, shows the anæmia of a secondary type characteristic of tuberculosis, with an increase in the leucocytic count. This is associated with constitutional symptoms and general feelings of ill-health. Some of the microscopic films showed poikylocytosis and deficient staining, but no abormal cells were seen.

INCIDENCE OF TUBERCULOSIS.

As indicated in the clinical notes, all cases are not tuberculous. It is extremely difficult to fix the onset of this infection. With the bronchitis associated with pure non-infective fibrosis there are mild constitutional symptoms. These disappear along with the catarrhal signs, but, from the frequent attacks of bronchitis, become almost continuous, till at length the tubercle bacilli which are inhaled daily in all probability gain a lodgment, and, in addition to causing local lung disease, poison the system with their toxines, producing a condition of general ill-health. Though the irritation of the lungs is going on insidiously for years, the onset of symptoms is often remarkably rapid.

Such an abrupt onset, for possibly in a few months the man may be so ill as to be unable to work, is suggestive of a more malignant agency at work than mere dust irritation. For, at the same time, he becomes conscious of a loss of strength and *bien être*.

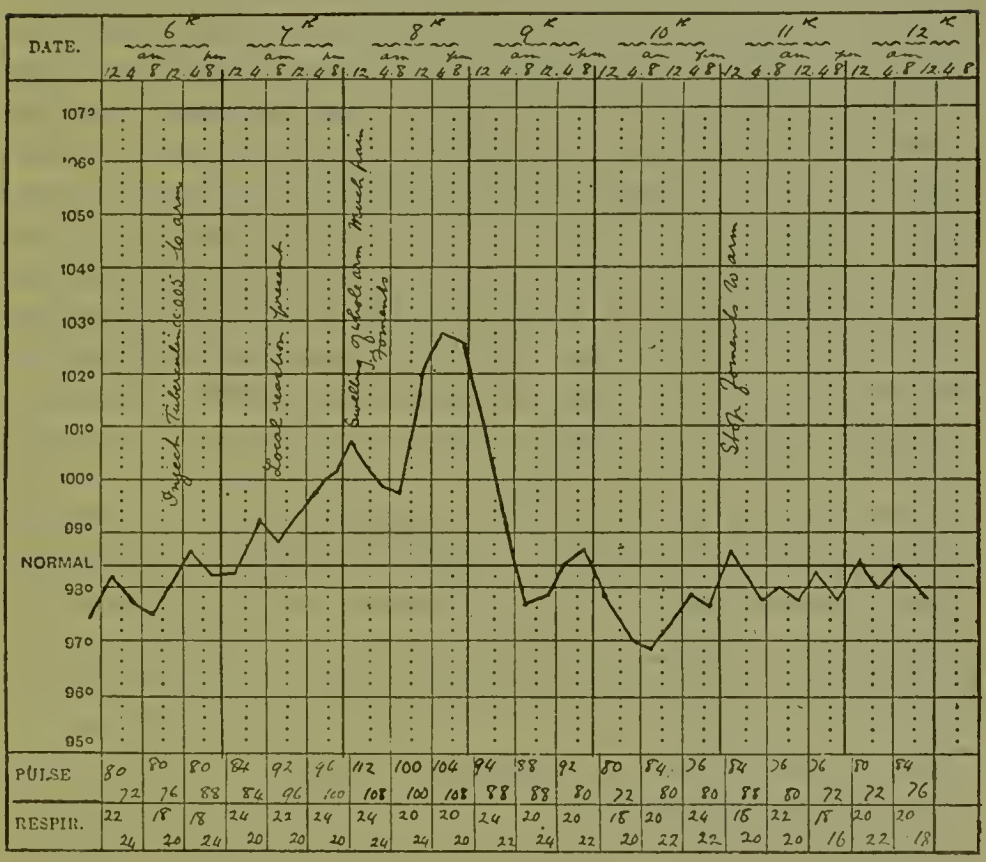
In arriving at the proportion of cases that are tuberculous, sputum examinations were made repeatedly before a negative result was decided on. In addition, the diagnostic use of Koch's old tuberculin was availed of in as many suspicious cases as could be persuaded to come under supervision for a few days. The dose injected was ·005 cc., and, in a few cases, the injection was repeated, giving as much as ·01 cc. Out of 13 cases so inoculated, two gave a definitely positive reaction, as seen by the accompanying charts. Check injections were given to cases known to be tuberculous, and also to healthy individuals.



THERMIC CHART. FOUR-HOURLY.

DR. Walter Summons WARD Medical

NAME Burns



Inclusive of the results of autopsies, out of 204 cases positive evidence of tuberculosis was obtained in 95—that is, 47 per cent. Though it is only justifiable to consider a case tuberculous if it is positively proved such, yet the clinical history and physical signs in several other cases left little doubt in my mind that they had been infected, but at the present time the disease was quiescent. Again, many other cases presented such symptoms that they might be simple bronchitis or early tuberculosis. In the absence of bacilli in their sputum, and as they were still working, they would not submit to a tuberculin test, no definite diagnosis at the time could be arrived at. Undoubtedly 47 per cent is a low estimate.

Out of the difficulty to determine accurately the prevalence of tuberculosis, several questions arise. Is there a type of case starting in the usual way, and progressing as a pure fibrosis, with recurring attacks of bronchitis and pleurisy, which, going on and on, finally brings about heart failure and death, without any superadded bacterial infection? And what is the cause of death in the lung diseases to which the miners are liable?

In reply to the second it can safely be concluded that at the present time all Bendigo miners dying of their respiratory diseases die of tuberculosis. This statement is based on the final ending in 27 almost consecutive cases—the only exception was that of one man who died of acute pneumonia, and who showed no signs of tuberculosis in his lungs. This series of cases also furnishes the answer to the former question. In reply to which I can only state, though it is conceivable that such an ending may happen, nevertheless I did not see any case to support a non-tuberculous cause of death. Tuberculosis is so prevalent that such susceptible cases become infected before the fibrosis and bronchitis reach so advanced a stage as to produce heart failure of themselves. There are, however, cases like the following one, when a man with acute rheumatism and cardiac valvulitis in youth becomes a miner, and develops a certain degree of fibrosis of the lungs. He died of heart failure, and the lung disease was not so far advanced of itself as to bring on the attack; far from it. The old valvular incompetence would have brought about premature cardiac failure, and although, no doubt, the ultimate end was hastened by the development of the lung disease, still this latter by itself did not produce heart failure.

For comparison, the prevalence of tuberculosis in other mining communities is given.

The Transvaal Medical Society's Report on Miners' Phthisis, published May, 1903, states—"It is not common to find the typical physical signs of tubercular phthisis present, and this observation, together with the confirmatory fact—that out of a series of over 30 sputa from cases of disease of the lung of miners examined, only two or three were found to contain tubercle bacilli—leads us to conclude that, while in some cases a true tubercular phthisis may co-exist or may be superadded, the conjunction is only seen in a minority of cases."

Dr. Thomas Oliver, in the "British Medical Journal" for 14th October, 1905, states, in an address on Rand Miners' Phthisis —"In some instances tubercle bacilli are detected, in others not at all. Since during life no tubercle bacilli are found in the expectoration, and after death none are found in the lungs, it is apparent that in Rand miners' phthisis we have an illustration of a true pneumokoniosis—that is, of a lung that has been irritated by dust, and in which, while the changes become progressive and ultimately lead to death, the malady from first to last can be non-tuberculous. . . ."

The cases Dr. Oliver examined had returned to England from the Transvaal, where they contracted the disease.

Dr. Ernest Black, in the Report of the Royal Commission on the Ventilation and Sanitation of Mines in West Australia, published February, 1905, states, though without actual figures on which to base his opinion—"The difficulty in drawing any conclusion from these as to the effect of the dust in our mines lay in the fact that, with one exception, they had all worked for years in mines in other countries, most of them in mines notorious for their high proportion of cases of miners' phthisis. Some of the cases investigated were evidently of the pure tubercular type, but in the majority there had been apparently fibrosis of the lung, followed by tubercular infection of the damaged lung. In only one case did I find pure fibrosis of the lung."

Dr. J. S. Haldane, in a report on the health of Cornish miners, concludes—"We thus have, as the gross results of the investigation, that out of 23 cases 17 were definitely shown to be tubercular. Further analysis of the cases shows that in 12 cases a history of the men having worked machine drills was obtained, and of these 8 were tubercular. Again, 9 of the men examined had worked in the Transvaal, and of these 6 were tubercular."

The inference to draw from these almost contradictory opinions, and the evidence obtained from the cases at Bendigo, is that the tubercular infection depends entirely on local conditions. If the disease is rare in the community, the chance of infection is diminished, and *vice versa*. Every infected case, however, whether miner or non-miner, if his sputum contains bacilli, is a danger to others, and unless precautions are adopted the percentage of tubercular cases will increase.

A useful clinical classification, therefore, is—

(1) A pure fibrosis of the lungs, non-tuberculous in origin, and which is a silicosis.

(2) The mixed type, with a tuberculous infection in a fibroid lung.

PATHOLOGY.

The pathology is based on the evidence obtained from 19 post-mortem examinations, and below are set out descriptions of 10 with the main facts in the clinical histories of the patients. This series exemplifies well the stages in the disease. The lungs from two miners of the class commonly regarded as healthy, but who were accidentally killed, show the early changes. Several others dying of diseases other than pulmonary furnish far advanced fibrotic and early tuberculous lungs. Finally are given descriptions of the lungs from miners who succumbed to their lung disease.

The nature of the changes is common, with the exception that some present a superimposed tuberculous infection.

My thanks are due to Professor Allen for courteously allowing me access to three pair of Bendigo miners' lungs in the Pathological Museum of the Melbourne University.

AUTOPSIES.

I. *History.*—Aged 35. Mining 10 years. Accidentally killed in a dynamite explosion. Health good.

Autopsy.—Body peppered from head to foot with small fragments of stone, several of which had perforated the abdominal wall and injured the intestines. There were signs of early peritonitis. Body well nourished.

The lungs showed thickening and opacity of the pleuræ, with black mottling underneath. On both sides there were interlobar fibrous adhesions, cribriform in nature, and a patch of adhesions to the parietal pleura where the right septum came to the surface, i.e., opposite the 5th rib in the axillary region.

On section, both lungs presented a uniform slate color, with numerous black areas, 1-2 m.m. in diameter, dotted about. Early emphyesma especially along the margins. Black pigmentation of the bronchial glands. No evidence of tubercle.

Microsocpic examination showed increase in the lung substance, with detachment of the alveolar epithelial cells, which were loose in the air cells, and here also were seen large and small nucleated cells, containing dust particles in their bodies. Evidence of catarrh was also present in the bronchioles and larger tubes. Deposits of dust granules were found scattered throughout the lung tissue especially, peribronchially situated. Some of these were black and opaque, others translucent, and showing lines of cleavage; both kinds were jagged, and presented many sharp points. The peribronchial collections produced the small black areas noticeable with the naked eye.

Intermingled with the dust were formative cells, and fully formed fibrous tissue, and also an increase generally in the cellular elements, with active, deeply staining nuclei. These were universal, pointing to a widespread irritation of a chronic character.

The subpleural tissue was evidently increased in the same manner, and included streaks of dust particles grouped together. Towards the superficial parts of the lung dilatation of the air cells was especially noted, but evidence of emphysematous changes were found here and there deep in the lung substance.

II. *History.*—Aged 33. Mining five years. Accidentally

killed on the surface. No illness or symptoms, and working up till time of death. Body well nourished.

Autopsy.—Organs normal save the lungs. These were similar to those of the last case, but though this miner had only worked half the time they showed greater pigmentation, which was more even throughout the lung on section. On enquiry it has been ascertained that the former (1) had been employed in some wet mines. Early emphysema was present in places, more especially towards the bases. There was a feel of toughness and of greater solidity of the lung substance than normally. No consolidation was found, and no evidence of tuberculosis.

The interlobar septa were occluded by adhesions, which also were present on both sides, uniting the visceral and parietal layers, but extending outwards from the septa.

The bronchial glands were deeply pigmented and enlarged. Cross-section showed small, whitish areas in the midst of the pigmented glandular tissue. Under the microscope these were found to be bands of white fibrous tissue cut at various angles, but they showed no trace of necrosis or other evidence of tuberculous infection. The gland tissue was almost replaced by masses of dust particles, interlacing around and between which were connective tissue fibres, while the glandular tissue was to a large degree masked by presence of the dust.

There was increase in the fibrous tissue at the root of the lungs and in the posterior mediastinum as evidence of a chronic indurative periadenitis.

III. *History.*—Aged 51. Mining 25 years. Symptoms pointing to lung disease present for three years prior to death, especially dyspnœa on exertion. Death resulted from asthenia, due to advanced epithelioma of the lower lip.

Autopsy.—Body much emaciated. There was a deeply ulcerating epithelioma of the lower lip, with secondary growths in the glands of the neck. No secondary growths found elsewhere.

Heart.—Right side flabby and dilated. No evident hypertrophy of the walls of the right ventricle.

Lungs.—Both small sized, with patchy pleural adhesions. Opaque pleuræ, with more evident opacities here and there. On section, the colour is uniformly black, with much increase in the toughness of the lung. Coarse emphysema generally scattered throughout the lung.

The bronchial glands were enlarged and deeply pigmented, and, as well as there being great increase in the fibrous tissue, definite bands passed into the lung substance from the root,

more especially accompanying the vessels and bronchial tubes. There was no evidence of tuberculous infection found.

IV. *History.*—Aged 79. Worked as a miner for 5 years prior to the use of machine rock drills, and more recently was manager for about 10 years. In between the two spells at mine work, he was engaged at work on the surface. Other than recurring attacks of bronchitis, he had no symptoms. Death was due to a chronic nervous disease.

Autopsy.—Body well nourished. Similar fibrosis and pigmentation of the lungs as in the preceding cases, but, in addition, at the right apex were a few old, well-formed pleuræ adhesions, with scaring on the surface of the lung. Subjacent to this were small fibrous pigmented areas in lung tissue. Under the microscope no evidence of tuberculous disease was found in this region. One of the bronchial glands at the root of the right lung showed signs of old caseation, and was partially calcified.

V. *History.*—Aged 33. Mining 11 years. Health has been failing for over 6 months, and patient had lost over a stone in weight. The feelings of malaise were not urgent, and the man had worked right up to time of admission to the hospital. He was suffering from an acute attack of appendicitis, and, though operated on immediately, died the next morning.

Autopsy.—Body wasted. Peritonitis was widespread.

Heart.—No increase in muscularity of its wall. Both ventricles were flabby. No valvulitis.

Lungs.—Both of small size. Many pleural adhesions, and some especially strong were at the left apex. On section the pleuræ were found thickened, and from them bands of fibrous tissue extended into the lung substance for short distances. At the left apex, subjacent to the dense pleural adhesions, strong fibrous bands passed right to the middle of the lobe, to where there was severe peribronchitis of a chronic character, with several bronchiectatic cavities. No tubercles were seen either in this region or elsewhere in the lungs, nor were there any bacilli detected in the bronchial secretion. The lung tissue was pigmented and tough with patches of emphysema. Several of the bronchial glands at the root of the left lung were caseating and softened, the colour of these being not quite so dark as the firm glands. Another contained a calcified, yellowish, old, tuberculous deposit.

VI. *History.*—Aged 51. Mining continuously for 29 years. Subject to coughs for years, and dyspnœa on slight exertion for 18 months only; muco-purulent expectoration, which contained many tubercle bacilli. Able to walk about at time of death,

but weakness and asthenic symptoms marked. Had only ceased working underground 8 months prior to death, which resulted from severe hæmoptysis. No spitting of blood before this.

Autopsy.—Tuberculous ulcers in the small intestine, and some turbid fluid in peritoneal cavity.

Heart.—Ventricular walls—both right and left—hypertrophied. Cavities on right side dilated, and walls flabby.

Kidneys showed a moderate grade of interstitial nephritis.

Lungs.—Pleural cavities both totally obliterated, and the lungs were so firmly adherent as to necessitate division of the adhesions with a knife.

On section the pleuræ were enormously thickened, being over ¼ inch across, whilst in some places the fibrous tissue was almost of cartilaginous consistency and appearance. On microscopic examination, however, the structure was seen to be well-formed hyaline fibrous tissue, with scanty elongate nuclei. The interlobar septa were completely obliterated, and there was much fibrous tissue around the bronchial glands, which were enlarged, pigmented, and fibro-caseous.

Left Lung.—In the upper lobe there was a large tuberculous cavity, excavating the greater part of this lobe and encroaching into the summit of the lower lobe. The walls were of tough, fibrous tissue, and on the apical side were about one inch through—this thickness being of fibrous tissue only—whilst on the pulmonary sides the fibrous tissue was intermingled with gross caseating tubercles. Across the cavity stretched strong fibrous bridles that had resisted the necrosis and softening process. The remainder of the lower lobe contained numerous coarse, fibro-caseous tubercles on a fibrous basis, giving a peculiar mottled appearance to the tissue. Towards the base was a little emphysematous crepitant lung tissue, but mostly the lung was airless, and the substance cut with the consistency of cheese. The whole structure, tubercles and fibrous tissue, was deeply pigmented, and marbled black in colour.

Right Lung.—The upper lobe and portion of the middle lobe contained many altered tuberculous nodules. Towards the apex was the beginning of a cavity formation. Remainder of lung was emphysematous, black, and indurated. Bronchial glands black and caseating on both sides.

VII. *History.*—Aged 73. Alluvial mining mostly; quartz mining at intervals for 15 years. No work at all for many years. Great dyspnœa and weakness prior to death.

Autopsy.—Body emaciated. Tuberculous ulcers in small intestines.

Lungs.—Many dense pleural adhesions, with well-defined rib markings. On section there was induration and pigmentation of the lung substance, with obscure tubercle, except towards the bases, where the tuberculous process was more recent and more acute, whilst towards the right base there was a concentration of the tuberculous process, with caseation and tendency towards a cavity.

The bronchial glands were caseous and calcified.

VIII. *History.*—Aged 59. Mining for 30 years. He was compelled to cease work five years ago, after a prolonged "attack of pleurisy" and general ill-health. Prior to this he was working continuously underground, but had dyspnœa on exertion, and was subject to attacks of bronchitis. Since then he has not been well enough to do any work.

Autopsy.—Organs, except the lungs, were fairly healthy, save for a slight grade of chronic interstitial nephritis. There was some hypertrophy of both ventricles of the heart.

Lungs.—Pleuræ were densely adherent, with thickening of the pleuræ, and again especially in lines running parallel to the ribs. The adhesions were not pigmented like the lung tissue itself. On a fibro-emphysematous basis were scattered coarse tubercles, and in the right lung, towards the apex, there was a small vomica, with corresponding scarring and puckering on the surface of the lung. In the lower lobe there was much fibrous tissue, giving a feeling of solidity to the lung, but in the centre of this portion, on section, was found an irregular cavity containing broken down tissue, evil-smelling, and in which were a large number of tubercle bacilli. The walls were softened and friable, with sparse tubercles, and it seemed as if the tuberculous softening was imposed on a portion of lung solidified from the overgrowth in the fibrous framework.

The left lung was similar, and also contained a cavity of like nature towards the base.

IX. *History.*—Aged 53; died 26th June, 1906, in Ward 21 of the Melbourne Hospital. Cause of death was heart failure. To Professor Allen I am indebted for permission to include this case.

Dyspnœa on exertion marked only for last nine months. Sudden onset of this symptom, but it gradually became more marked. Cough continuous for 12 months, and at intervals prior to this. No hæmoptysis. Patient is weak, and stated he lost three stone in weight during the last nine months.

Autopsy.—Right lung contained four well-defined fibro-caseous nodules. These varied in size from three inches to about one inch in diameter. Two were in the upper lobe, and two in the middle, one of these latter projecting on the surface of the

lung, and simulated greatly a secondary malignant growth. The two smaller ones were composed of bands of fibrous tissue, and caseating tuberculous matter filled the interstices, giving a laminated appearance to the tumour, and also showing its chronic nature. The larger two had cavities in their interior, surrounded by fibro-caseous lung tissue, distinctly marked off from the surrounding lung substance. There were no scattered small granulomata, but both lungs showed the characteristic changes associated with the dust inhalation, viz., fibrosis, pigmentation, and coarse emphysema. Left lung was similar to right.

X. *History.*—Aged 54. Started mining æt. 23; worked last eight years ago. Three years prior to that time he had shortness of breath, black, frothy expectoration, and much asthenia; but for last six years he has gradually been going down hill.

Autopsy.—Body emaciated, and extremities œdematous.

Lungs.—Right lung collapsed, fleshy, black, and almost airless; a tuberculous cavity occupied the upper half, and several bronchiectatic, smaller cavities were scattered here and there towards the base. The lung was totally adherent to chest wall and diaphragm, and the heart was displaced to the right. On lower surface of the right vault of the diaphragm were numerous small tubercles.

The left lung was firmly adherent at apex, and the interlobar septa was obliterated, whilst in the region of the pericardium, as elsewhere, there were scattered well-formed adhesions, and associated with them was some adherent pericarditis. Elsewhere on the surface of the lung were numerous whitish nodules and lines of tuberculous tissue, and from many of these faci well formed, but thin, pleural adhesions arose. The subpleural lymphatic infection was extremely well marked.

On section of this lung a vomica was found in the apical portion, and numerous pigmented tubercles elsewhere throughcut the lung on a fibrous, pigmented basis.

HISTOLOGICAL SECTIONS.

1. Early silicosis in bronchial gland
2. Early silicosis in lung, the patient dying from an accident.
3. Gland infected with tuberculosis, the patient being otherwise free from tubercule, and dying of appendicitis.
4. Advanced lung changes—no tubercle detected in this section, but the patient died from tuberculosis.
5. A fibrous nodule or false tubercle from the same patient as section 4 was taken.

6. Advanced lung changes, with superadded tuberculous infection, the patient dying of tuberculosis.

7. Very advanced changes in a bronchial gland.

Section 1.—This section may be taken as typical of early dust irritation. Microscopically, pigment granules are visible in all the gland sinuses where the lymph nodules are, for the most part, normal, containing little or no pigmentation. Under the capsule in certain parts deep pigmentation is present. There is a great increase in the fibrous tissue elements everywhere, noticeably in the capsule trabeculæ and around vessels, but nowhere did it form large areas as it did in section 7. Although destruction of the true lymph element is starting, it has only advanced slightly.

Section 2.—In this section large areas of lung or microscopic examination are seen to be fairly normal and the visceral pleura free from evidence of old pleurisy. In areas of lung where changes had taken place many alveolar spaces appear normal but tend to be more distended than in a healthy lung. The pigmentation very definitely is seen to be in and around the perivascular lymphatic vessels, and here the fibroid changes seem to be more marked than anywhere else in the lung. No evidence of acute inflammation exists, no clumps of round cells being visible, the vessel walls and the procesess of fibrous tissue extending from them show great thickening, and are pigmented. All the charges from fibroblast to fibrous tissue may be traced. All this going on quietly, without lemocytic reaction, and with no giant cell systems or single giant cells. In this way fair-sized islands of fibrous tissue had been formed, and, as noticed in nearly all the sections here and there, the fibres were not well differentiated, but produced patches of hyaline fibrous tissue, staining faintly, and showing few nuclei, and with an almost absense of fibrillation.

The other site where changes had occurred was in the alveoli. In a few places the cells lining the space were shed, and the space filled with fibrin clot, which was gradually being invaded by fibroblasts. The alveolar walls were thickened, again partly due to the increase of the fibroblastic elements, and partly the result of the presence of pigment granules in the inter-alveolar tissue. In many fields, however, this process had progressed much further. Perhaps only one or two adjoining alveolar spaces had become obliterated, and formed a patch of lowly-formed, fibrous tissue. In other places many spaces were obliterated and all trace of alveolar wall had disappeared. Here all stages of fibrous tissue formation could be seen and new blood vessels traced. Irregular pigmentation was everywhere present, and in many

places the fully-formed, fibrous tissue had a concentric arrangement round an area of pigmentation. Elsewhere a similar arrangement held but the core, as it were, was not pigmented, and apparently these fibrotic areas were the remnants of normally existing blood vessels or small bronchioles.

No pigmentation, the result of hæmoglobin destruction, was seen, but the particles were either quite opaque or crystalline and translucent. The flaky crystalline quartz particles showed innumerable jagged edges, but were not present to anything like the extent of the opaque silurian rock particles.

Neither in this section nor in the previous one was there any evidence of tuberculous infection, simply the dust pigmentation, the loss of the lymphatic elements, and the fibrosis. The main changes brought about in consequence of the inhaled silicate dust briefly are:—

(1) Peribronchitic and interlobular pigmentation.

(2) Chronic catarrh in the fine bronchioles and filling up of alveolar spaces with catarrhal elements.

(3) The exudate is gradually removed and replaced by formed fibrous tissue. This fibrous tissue is intimately connected with the alveolar wall, and, adjoining small areas having coalesced, pigmented, fibrous areas are produced, showing no evidence of alveolar wall.

(4) Great increase in the fibrous tissue elements round lymphatic and vascular channels.

Section 3.—Bronchial gland from autopsy V.

Microscopically, the glands were much pigmented, and showed considerable periadenitis, with matting together. On section two of the larger ones were found caseous.

Microscopic Section.—Save towards one end, nearly all the true lymphoid tissue had diasppeared, and even here there was an excess of fibrous tissue. More centrally all the lymphoid tissue was wanting, and ground substance consisted of fibrous tissue, some of the fibres arranged in whorts, others in straight lines, and others in recticular fashion. Nuclei were scanty. In the recticular portion the fibrous tissue was so slightly differentiated that areas looked hyaline, with very feeble formation of fibrils, very scanty nuclei, hardly any blood vessels, and staining almost uniformly with picric and fruit. Black pigment was everywhere scattered irregularly throughout this fibrous tissue. In parts the pigment seemed to have some arrangement either in lines or circles, apparently lying in the remains of lymph sinuses. The maximum intensity of the pigmentation was under the capsule. As the caseous area was approached scattered giant cell systems were seen, all, for the most part, staining indis-

tinctly. Lymphoid cells were scanty, and the system composed of a poorly stained giant cell, surrounded by epithelioid cells. The caseous centre contained no cells, and stained diffusely with picric acid. Calcification has occurred at the margin of the lung area. The chief points noticeable were the changed nature of the gland from lymphoid tissue to fibrous tissue, the poor staining reaction of the formative cell nuclei, and the innumerable granules of pigment in all cases.

Section 4.—This and the next section were taken from a subject with advanced lung disease, who died from tuberculosis. The bronchial glands were enlarged and caseous, whilst the lungs were solid in some areas, and showed extensive tuberculous changes. This section is taken from the most normal-looking part of the lung. Many alveolar spaces were, under the microscope, found obliterated and represented by fibrous tissue deeply pigmented. Adjoining spaces were irregularly enlarged, and showed loss of lining, epithelium, and marked inflammatory changes, containing fibrin, leucocytes, and large cartarrhal phagocytic cells. The alveolar walls in the neighborhood showed small, round-celled infiltration and fibrosis in all stages of formation and pigmentation. The pigment granules, as well as, for the most part, presenting the characteristics of the dust particles also in some places were translucent and brown in color, these latter probably being derived from breaking-down hæmoglobin, which had been extravasated in consequence of the inflammatory changes.

In other areas the chronic fibrosis had not been disturbed by secondary inflammatory changes. Increase in size and irregularity of the alveoli were widespread, and were the beginnings of the marked emphysema seen in other portions of the lung.

Section 5.—This was taken from the same lung as the last section, but from one of the completely solid areas. Not the slightest remains of alveolar structure could be detected; but the whole section was made up of strands of fibrous tissue arranged in fantastic manner, in bands, in whorls, and reticular fashion. The whole constituted a "false tubercle," and around a centre of hyaline tissue the fibres were arranged more or less in concentric layers, staining diffusely with eosin or picric, and containing few nuclei. The whole was deeply pigmented with the black sylicate particles. Well formed vessels, with thick walls, run between the strands of fibrous tissue. The chronic nature of this nodule is evident. The more recently formed ones were more cellular.

Sections four and five were taken from areas of lung where the tuberculous infection had not reached.

Section 6.—This section was taken from a well-marked, fibrotic lung, with advanced tuberculous disease superimposed. Portions of this section were identical with those already described, showing the fibroid tissue and catarrhal changes in the alveolar spaces. The whole, however, was more inflammatory, as indicated by the leucocytic reaction. As a tubercular focus is approached more nuclei are noticed. In a tuberculous area the section differs little from that of ordinary phthisis, save for an excessive amount of fibrous tissue and pigmentation between the tuberculous systems. There are alveolar spaces filled with fibrin, leucocytes, and large catarrhal cells, areas where all trace of alveolar wall has disappeared, and in which there are distinct tubercular nodules, with caseous centres and small round and giant cells in the periphery. Much pigment is seen right up to and within the tuberculous foci. The tubercles have the ordinary structure and exhibit strongly their chronic nature by the amount of fibroid tissue towards the periphery. Towards the margin of the section a patch of caseation breaking down into a cavity is seen.

Blood vessels are scanty in the tuberculous sections, but in the surrounding tissue thick-walled ones are seen. The increase in thickness is due to an excess of fibrous tissue in the adventitious coat.

The essential pathology of miners' phthisis is thus seen to be a fibrosis of the lungs, with an associated chronic irritation of the bronchial tubes, consequent upon which coarse, emphysematous changes ensue, and sooner or later infection with the tubercle bacillus takes place, with the resulting formation of tubercles, caseation, and formation of cavities. The tuberculous process is altered somewhat from the fact that the tissue affected is not normal but fibrotic lung tissue.

Microscopic examination in the early cases shows the desquamation of the ciliated lining epithelium of the bronchi, with the signs of a chronic catarrh. This destruction of the protecting cell layer facilitates the penetration of the lung tissue by the dust-laden, amœboid phagocytes, and even by the angular dust particles themselves, which are found in innumerable numbers embedded in the lung tissue. The particles correspond in shape and size and appearance to those suspended in the mine air. Primarily the dust is carried to the peribronchial lymphatics, and shortly the glands at the root of the lung become pigmented and marbled black, and, finally, jet black, and microscopic sections show the glandular tissue almost entirely destroyed and replaced by opaque, black particles. Here and there, however, are small translucent areas free from dust. These are bands of

fibrous tissue, cut at various angles, showing marked hyaline changes, with little evident fibrillation. They show no signs of softening or caseation. When tuberculous caseation and necrosis does take place, the softened tissue is black in colour, due to the amount of bluish silurian rock dust entangled in the meshes of the glands.

The dust particles are seen to lie, on the whole, in elongate, well-bounded areas, which are the lymphatic vessels blocked by their presence. In all the alveoli, as well as in the bronchioles and larger tubes, signs of catarrhal inflammation abound in the proliferation and shedding of the epithelium and the presence of phagocytic cells free in the alveoli and closely packed with dust particles. In the lymphatics many of these particles are dropped, perhaps as the result of the death and disintegration of the phagocytic cells. Being deposited in the tissues, the jagged edges set up a low, chronic inflammation, with the production of formative cells and fibrous tissue, which envelops the irritating particles. However, with the development of this fibro-connective tissue there is no fresh production of new blood vessels, while the already existing ones in many places become occluded. Thus the newly-formed tissue interferes with the respiratory processes, and, being of low vitality, has small germicidal power. The absorption of fresh supplies of the irritant increases the formation of fibrous tissue, and, by its contraction, small areas of the lung are separated off and cease from functionating. Not only is the irritation primarily around the bronchial tubes and blood vessels, but it is also most intense there, with the result that the lumina of both sets of vessels are diminished, and in some places they are compressed altogether, and are represented solely by small, fibrous areas.

A lesser division of the lymph drainage goes from the superficial parts of the lung to the root by way of the subpleural spaces. As a consequence of this, the dust being deposited in the same way, brings about a general opaqueness of the visceral pleura, with here and there denser opacities and elongate, fibrous plaques, simulating the tuberculous formations found in this situation, and in one lung both non-tuberculous and caseous tuberculous areas were present.

The dust pigmentation on section of the lung in the early stages is in small areas, but later on the discoloration becomes more and more uniform and darker, with the most intense changes in the bronchial glands and beneath the pleura, till, finally, the lung becomes jet black.

With the violent expulsive efforts to get rid of the mucus from the air passages, increased air pressure in the alveoli is a constant occurrence. Dilatation of the air cells results, becoming of coarser grade as time goes on. The whole result of the fibrosis is a tough, fleshy lung, inky black in color, and of normal or somewhat contracted size. Coarse emphysema is scattered almost uniformly throughout its substance, but there are no large blebs at the margins. The substance is slightly gritty to cut, and, on pressure, a blackish fluid exudes. The condition is more than a widespread bilateral peribronchitis, for the whole substance of the lung is increased, but especially so in the neighbourhood of the bronchial tubes; and the condition may be regarded as a chronic slow pneumonia. The lung has undergone a process of carnification. The fibrosis is of similar distribution to the tough lungs met with in syphilitic cases. In these, however, there is no pigmentation, but the lung presents the white appearance so characteristic of the disease. Also here there is endarteritis, as well as periarteritis, while in the miner's lung no arterial disease is found save the compression from outside the vessel.

For the inorganic constituents of a Bendigo miner's lungs I am deeply indebted to Mr. Gustav Ampt, who carried out a very careful analysis at the Melbourne University, under the direction of Professor Masson. The lungs were dried, and the weight of the dried material was 275·5 grammes. In this condition examination with a pocket lens showed many white particles, some decidedly crystalline—these possibly being particles of quartz. After incineration the weight of the ash was 13·1101 grms.—that is, $4\frac{3}{4}$ per cent. of the dried material. To dissolve the slag, it was treated with $KHSO_4$, and $KNa\ Co_3$; and hence it is obvious the $Na_2\ O$, K_2O, Na Ce, and So_3 could not be determined.

The final statement is, in Mr. Ampt's own words—

Constituent.	Weight.	Per cent. of total ash.
Silica ..	5·3127 ..	40·52
Alumina ..	4·3851 ..	33·45
Ferric Oxide ..	1·2914 ..	9·85
Lime ..	·0471 ..	·36
Magnesia ..	·1645 ..	1·25
Phos. Pentox. ..	·4263 ..	3·25
Constituents found	11·6271 ..	88·68
Total Ash ..	13·1101 ..	
Na Cl, Na_2 O K_2 O, SO_3 by difference	1·4830 ..	11·32

For the sake of comparison, I include Hammarston's analysis of the ash of a normal lung, and it will be seen that there is no similarity whatever.

	Normal.	Diseased.
$Si O_2$ ..	13·4 per cent.	.. 40·52 per cent.
$Al_2 O_3$ ..	——	.. 33·45 ,,
$Fe_2 O_3$ ..	3·2 ,,	.. 9·85 ,,
Ca O ..	1·9 ,,	.. ·36 ,,
Mg O ..	1·9 ,,	.. 1·25 ,,
$P_2 O_5$ ..	48·5 ,,	.. 3·25 ,,
Na Cl ..	13·0 ,,	
$Na_2 O$ ..	19·5 ,,	.. 11·32 ,,
$K_2 O$ ..	1·3 ,,	(by difference)
So_3 ..	·8 ,,	
	103·5	

The most striking figures in the "normal" analysis are $P_2 O_5$ = 48·5 per cent., and $Al_2 O_3$ = 0. To my mind, this seems very "abnormal," especially when on writing down the $P_2 O_5$ equivalents of all the basic oxides, there remains nearly 11 per cent. of free $P_2 O_5$ thus :—

As $Na_2 HPO_4$	2 $Na_2 O$	∴	$P_2 O_5$	=	22.3
$K_2 HPO_4$	2 $K_2 O$	∴	$P_2 O_5$	=	1·0
$Ca H_4 (PO_4)_2$	Ca O	∴	$P_2 O_5$	=	4·8
$Mg H_4 (PO_4)_2$	Mg O	∴	$P_2 O_5$	=	6·7
$Fe PO_4$	$Fe_2 O_3$	∴	$P_2 O_5$	=	2·8
					37·6

∴ free $P_2 O_5$ = 11 per cent.

Is it, perchance, possible that $Al_2 O_3$ is included in the $P_2 O_5$?

Supposing this to be the case, then a peculiar coincidence is noticed, viz.:—

	Normal.	Diseased.
$Si O_2$	13·4 × 3 = 40·2	40·5
$Al_2 O_3$	11·.. × 3 = 33·0	33·5
$Fe_2 O_3$	3·2 × 3 = 9·6	9·85
Na Cl, $Na_2 O$ $K_2 O$, SO_3	34·6 ÷ 3 = 11·5	11·3 (by difference)

of course, I regard this as a mere coincidence, nevertheless it is very striking."

The important difference is in the silica. Normally present to the extent of 13·4%, the miner's lung contain 40·5%, or three times the former amount. The lung analysed for this investigation was in but a moderately advanced grade of silicosis, and presented only a patchily pigmented appearance. The proportion of silica, however, adequately shows the important part it plays in the abnormal lung condition. The presence of

aluminium to the extent of 33·5% of the ash is abnormal, and in large measure accounts for the fibrosis.

In a great number of cases pari passu with the development of the lung fibrosis, a slow inflammation of the pleuræ has been progressing, spreading out from the root along the interlobar fissure. Autopsies I. and II. illustrate this. The adhesions are scattered to begin with, but they become continuous, and first the interlobar septa, and, ultimately, the whole pleural cavity, is obliterated, and the lungs become totally fixed to the chest wall. The thickening of the pleural and the adhesions, though diminishing the lung expansion, are protective against the development of pneumothorax. The signs of chronic dry pleurisy were most constantly found on clinical examination, and post-mortem adhesions were invariably present, and in some cases the pleural cavity was totally obliterated.

What is the nature of this pleurisy? In some cases it is secondary to lung involvement, but then the site is frequently apical, and there are signs of consolidated or breaking-down lung, with probably tubercle bacilli in the sputum. In many cases the first physical signs, however, are slight creaking heard at the sides in the region of the 5th interspace. The pleurisy in these cases is secondary to bronchial gland involvement, and again may be of tuberculous origin. Many other cases not suggestive of tuberculous infection, and, indeed, some giving a negative tuberculin test, presented signs of pleurisy, and the non-tubercular nature is shown by the autopsies I. and II. The pleurisy is not due to the direct irritation by the dust, as the adhesions are not pigmented, but the origin is from around the bronchial glands, where there is already a peri-adenitis and a marked increase in the fibrous tissue of the mediastinum. This mediastinitis must be caused by a mildly septic inflammation spreading from the lymphatic glands, whose functions are interfered with by the dust particles. Once the formation of pleural adhesions is commenced, the constant lung movement tends to make them progress, and, as it were, take on a keloid nature, for, even when movement of one pleural surface on the other becomes impossible, the fibrous adhesions go on growing, and become very tough and almost cartilaginous in appearance, but the cells remain elongate, and are not those characteristic of fibro-cartilage. Other pleurisies are acute and of infective origin. These present a variable amount of effusion and are often more evident on one side, or, perhaps, are unilateral only. This acute form is rare as compared with the frequency of the chronic dry type.

The contraction of the adhesions and the lung changes bring about displacements of the heart, and not infrequently there is

pleuro-pericarditis, and, as seen by the Rontgen rays, diminished mobility of the diaphragm.

As the net result of these changes, there is diminished elasticity of the lung, with impairment of chest expansion. This is still further diminished by the dense pleural adhesions, which produce as well in some cases immobility of the diaphragm. Added to these are emphysematous changes in the lungs and an associated bronchitis. All increase the liability to tuberculosis, and though the constitutional susceptibility of the miners, as shown by their opsonic indices, is high, the lung changes make them, as a class, extremely liable to infection by the ubiquitous tubercle bacillus. The damaged tissue, when once infected, has but little chance of again gaining the upper hand, and a fatal result sooner or later ensues.

The site of the infective process is, as in ordinary phthisis, usually apical, and, if at the bases, tubercles also were found scattered throughout the lungs, concentrated, perhaps, at one or both apices. The infection, in most cases, is chronic, and necrotic processes slow, and, in addition to the fibrosis throughout the lung generally, there are localised fibroses produced by and encapsuling the tuberculous focus. Thus in some instances the whole lobe may be solid and airless, with the fibro-tuberculous process, yet caseation had gone on to softening so slightly that perhaps merely a small vomica, with tough, fibrous walls, had been formed. In another case (Autopsy IX.) there were three fibro-caseous nodules of large size—one three inches across—that could be mistaken for secondary nodules of a malignant growth. Here the infective process was distinctly localised and made up of fibrous bands, more or less concentrically arranged with caseation of the intervening tissue, whilst the lung tissue between these foci was pigmented, fibrous, and emphysematous, but presented no tubercles.

The tuberculous nodules infiltrating the pigmented tissue, not replacing it, were likewise pigmented, and the "black spit" that persists even after the miner had ceased work underground is due to the presence of this softened lung tissue in the expectoration. As well as the pigmentation produced by the inhaled dust, the chronic lung congestion and the small extravasations of blood give an additional discoloration, and is seen more particularly in the portions of lung adjacent to the tuberculous foci. In the centre of these sooner or later softening occurs and cavities form. The walls, however, are extremely thick and fibrous, and the necrotic process is somewhat slow, whilst the bridles coursing across the cavities are thick and resist softening for a long while. Hence the reason for the comparative rarity of ulceration into the vessels and hæmorrhage.

In many of the tuberculous lungs irregularity in the size of the bronchial tubes was noted, in only one was there a definite formation of bronchiectactic cavities (Autopsy V.). In this case the dilations were localised to the middle of the upper lobe, with ill-defined tubercular-fibroid tissue around, and on the surface there were dense pleural adhesions, from which bands of fibrous tissue passed into the lung tissue, and joined with the fibrosis around the dilated bronchi.

Any and all pathological lungs changes may obtain in the miners' lung, but the common changes are dust, pigmentation, and fibrosis primary, with emphysematous changes, and, at some time or other, infection with the tubercle bacillus occurs, and the pathological changes peculiar to the inroads of that organism are altered somewhat as the tissue affected is not normal but a fibroid lung.

ETIOLOGY.

The excessive mortality amongst the Bendigo miners being the result of lung diseases at once suggests vitiation of the air as the probable cause. The nature of the impurities in mine air was fully discussed in my preliminary report on mine ventilation. It was therein shown that the important difference in the air of quartz mines, as contrasted with that of alluvial mines, was the presence of rock dust. The carbonic acid gas is in excess in the alluvial mines, and yet there is no lung disease peculiar to, or especially prevalent amongst, the workers in these mines. Common, moreover, to both kinds, and to all other mines is the absence of sunlight. The cause or causes, however, should be looked for in conditions that occur in one group and not in the other; and again the same or a similar one must co-exist under other conditions to produce a similar disease of the lungs in classes of men engaged at other occupations. Thus, notwithstanding the presence of sunlight with stone-masons, file-grinders, and the like, the dust inhaled at such occupations produces a fibrosis of the lungs similar to that common in quartz miners; whilst alluvial miners who are free from dust inhalation are not liable. Coal miners and coal lumpers inhale a dust of a different nature. Not only are the particles of coal dust much larger in size, and on that account when inhaled are more likely to be deposited in the mucous secretion of the larger bronchial tubes, but also when absorbed into the lung tissue do not possess the irritating character of the silica particles. These latter, extremely minute and flaky, remain suspended in the inspired air just as they do in the mine air, and a far greater proportion of them reach the alveoli of the lungs. [See sketch, p. 24, Ventilation Report.]

Silica dust is therefore to be considered the cause of non-tuberculous miners' phthisis. It is constantly found in their lung tissue, enveloped by fresh fibrous tissue formed in consequence of its presence; and, even after many years, presents the same appearance as when it was inhaled. On incineration it was regained from the lungs, and by chemical analysis shown to be of the same nature as the country rock of the Bendigo mines. Without the dust no lung disease is prevalent, hence it, and it alone, is the sole cause of miners' phthisis (non-tuberculous), and it can safely be asserted that, with the absolute prevention of dust, the lung disease would almost cease to exist. The other sources of air vitiation, as noxious fumes, are adjuvant causes, but of themselves do not produce sufficient detriment to health to bring about lung disease.

Miners' phthisis (non-tuberculous) is thus a typical example of a disease brought about by the mechanical action only of dust particles, without absorption of them, and with no poisoning of the system generally. It is a disease of purely local origin, and continues as such till tuberculosis, with its specific bacillus, is superadded, and poisons the body with its toxines, and, in addition, produces alteration in the nature of the pathological changes in the lungs.

There is now to be discussed the other important etiological factor in the disease—the infection by the tubercle bacillus. It, as has been seen, obtains to the extent of 47 per cent. at least in the cases, while it is the cause of death in all cases dying of their lung disease, saving the small proportion that are carried off by acute pneumonia, which is but slightly in excess of the percentage of fatal cases of pneumonia amongst adult males.

Determining the susceptibility of the miners to tuberculosis, I found the opsonic indices of ten miners suffering from fibrosis (non-tuberculous) of the lungs as given in the following list. In the second table are the results of a similar estimation in ten tuberculous miners, and, for comparison, in the third column are placed the opsonic index in ten cases of consumption amongst adult males, non-miners.

OPSONIC INDICES.

Miner's Phthisis. (non-tuberculous).		Miner's Phthisis. (tuberculous).		Phthisis. (tuberculous in non-miners).
1·16	..	1·3	..	·8
1·1	..	1·2	..	·75
1·1	..	·80	..	·65
1·01	..	·74	..	·6
1·0	..	·66	..	·6
1·0	..	·63	..	·5
·92	..	·62	..	·5
·88	..	·62	..	·46
·8	..	·57	..	·4
·7	..	·54	..	·4

The first table shows that miners, as a class, in no respect differ from healthy male adults in their normal resisting power to infection. The great prevalence of tuberculosis amongst them thus is due to the lowered vitality of the damaged lungs, and when infection does take place, the opsonic index becomes subnormal, and corresponds to that of ordinary consumptive cases. In the second group, however, two cases show a high index. The first one was an early case, though bacilli were found in the sputum, and the second one was diagnosed tuberculous by a positive tuberculin reaction.

Where does the tuberculous infection take place?

The possibilities of infection underground from miner to miner are, as stated in the preliminary report, great so long as infected miners are permitted to go below; but apart from such direct infection from man to man, the chances of contracting the disease are remote, seeing that guinea pigs remained unaffected, though living altogether in the mine air. The indiscriminate spitting, however, of tuberculous miners is to be deprecated, much more so away from fresh air and sunlight than even on the surface. Every fresh case of tuberculosis owes its origin to a pre-existing case with which the individual has come in contact, or from which bacilli have been disseminated. Though a healthy person may live in the same house, or even in the same room, with a phthisical person without infection resulting, we must look on such a close relationship as being the agency in many cases. In 33 out of the 95 tuberculous miners, some of the near relatives had died of consumption, and, in one case where the father and two brothers had died of "miners' complaint," and one sister of consumption, the disease is the family scourge. In Bendigo there are certain houses that may be termed tubercle houses, which several families had occupied in turn, and I was informed that some of these dwellings have never been free from a case of consumption, the whole family, in some instances, dying of the disease, whilst individual affected members, having moved elsewhere, became fresh centres of infection. In such ways, from carelessness in the discharges and in the washing of the linen, as well as by exhalations from the patients themselves, infection is disseminated. In spite of the efforts of public bodies, and the futile attempts to educate consumptives as regards the necessity for their own personal cleanliness, it still holds that phthisical patients, as a class, are extremely negligent of minimising the risk of infection to others. There is no evidence that miners become infected differently from other individuals, though it is probable that a minority are infected while at their work. The bacilli inhaled come directly or indirectly from some pre-exist-

ing case of consumption, and the infection occurs in their own homes or at places of public resort.

The two factors are to be looked on as the causes of miners' phthisis, but there are predisposing conditions. The oppressive heat and moisture of the mine air do not appear to be highly injurious, as stokers and dwellers in tropical climates are subject to similar conditions. The sudden change of temperature on ceasing work and coming to the surface is attended with greater risk. After working night shift in, perhaps, a temperature of 95° F., the rapid passage to an atmosphere of probably less than 45° F., on a frosty morning, produces a shock to the miner. If, however, a lukewarm shower bath is taken without delay, and the wet working clothes changed for warm, dry flannels, the rapid alteration in the temperature of the surroundings is not so keenly felt. Nevertheless, the up journey, in a strongly downcast shaft especially, as taken by many of the younger and more thoughtless miners, with insufficient covering, is even more severe than they are able to bear with impunity. These repeated chills day after day tend to aggravate any existing respiratory disease, and to render the way more easy for bacterial invasion to occur. On the majority of the mines warmed "change-houses" are available in close proximity to the mouth of shaft; but time after time, though remonstrated with by the managers, the miners neglect to take a shower and change their clothes. Such chills are minor factors in the causation of respiratory disease, for coal miners and others are subject to similar conditions, and no great prevalence of respiratory disease exists amongst them.

The gaseous vitiation of the mine air were treated of in the section on mine ventilation. These frequently set up a temporary irritation of the respiratory passages, which passes off on the inhalation of purer air; but, repeated day after day, a chronic catarrh of the bronchial tubes is brought about, with destruction of the lining epithelium. The fumes are greatly assisted in this irritation by the dust particles inhaled at the same time. The discomfort of working in the badly ventilated mines has a depressing influence on the men, though, as they are accustomed to say, they make the best of it. The impure atmosphere, quite irrespective of the presence of dust, renders those working in it continuously extremely liable to tuberculosis. The results of observations again and again in gaols and surface workshops prove the tubercle bacillus to be the Nemesis of defective ventilation. It is therefore imperative that improvement be brought about in the mine ventilation at Bendigo.

The miners are underground for one-third only of the 24 hours, and the remaining two-thirds should be so spent in recreation

and rest that the detriment to health due to the day's work should be recovered from, and a fresh stock of energy laid by for the following day. In a great many cases the recuperative powers are hindered from having full sway. In common with all other depressing occupations, the craving for stimulo-sedatives amongst miners is abnormal, whilst the temptations and opportunities for satisfying this craving are abundant. Alcohol, by inhibiting the activity of the phagocytic cells, renders the individual more open to bacterial infection.

A passing comment must also be made on the housing of the miner. The great majority live in weatherboard houses, and around all there is ample air space. A most noticeable deficiency, however, is the almost entire absence of ventilators, whilst the windows, other than those facing the street, are often not larger than a foot square, opening, it may be, only halfway. When on night shift, the miner is compelled to sleep during the day-time, and, instead of shutting the room up altogether, he should accustom himself to sleeping with some degree of light, and with the window or door open, so as to keep the room air pure. In the case of an invalid, the room chosen for him frequently is the most unhygienic in the house. To place him in close communication with the rest of the family, his bed chamber frequently had a window and a door opening off the living room, but had no communication with the outside air, or else there was one of the small windows mentioned above in the external wall. The drainage, as might be expected in a city that has rapidly grown, has many faults. Far too frequently do the drains lead only into the nearest gully.

The hygienic deficiencies are of minor import as compared to the damage to the lungs underground in maintaining the high death rate due to tuberculosis. All, however, play their part in the etiology of the disease, and indifference to sanitary and hygienic laws brings its own penalty.

PROGNOSIS.

In the silicosis the outlook is good, provided the miner ceases work underground before great damage to the lungs takes place. With improvement in his general health, brought about by change of occupation, the symptoms become less urgent. If, however, the fibrosis is advanced, the outlook is bad; sooner or later, unless carried off by some intercurrent disease, tuberculosis is superimposed, and death intervenes. This infection, as shown by the post-mortem results, is not necessarily fatal; but the chance of recovery with previously damaged lungs is remote. With suitable care the disease can be checked some-

what, as in advanced cases of ordinary consumption, and the patient's life greatly prolonged.

The mode of death is most commonly by gradual asthenia, with marked emaciation, and, finally, syncope. In a small proportion of cases œdema of the extremities is a marked symptom some time prior to death, and death comes about from myocardial failure. Hæmoptysis is decidedly rare as a symptom, but in one case it was the final ending.

The duration of life, as stated before, subsequent to tuberculous infection, is about five years, or a little longer than the average case of consumption amongst non-miners.

PROPHYLACTIC MEASURES.

In the report on mine ventilation some advisable improvements were brought forward, and emphasis was put on the necessity of the more rigid enforcement of the laws relating to the suppression of dust. To supplement what was then suggested, it may be stated that there are three mehods of controlling the dust nuisance—

(a) At the place of origin.

(b) From circulating in the mine air.

(c) By filtering the air as the men inspire it. The second may be dismissed as a practical impossibility, whilst the third brings in the subject of respirators. However efficient these may be, they cause embarrassment to respiration, and there is necessarily excess of carbonic acid gas in the enclosed air space. Miners everywhere quickly tire of their use and discard them altogether. There is thus only left the prevention of the dust at its origin.

Dust is formed in most mining operations, in blasting, in shovelling, and throwing the rock and quartz down the shoots, and, above all, in rock-drilling. Each and all must be dealt with in securing the freedom of the air from dust particles. The unwillingness on the part of the individual miner to use a water jet with the rock drill is almost beyond comprehension. The beneficial effects of water after blasting is well known, and buckets of water are frequently thrown down a winze or shaft after blasting; but it is better to employ a smaller quantity of water in a more efficient way, as a jet, or mixed with air as a fine spray. Water under any pressure and compressed air are to be had in all the mines. Again, in shovelling work a spray will damp the rock and thereby minimise the formation of dust, and that, too, at no inconvenience, but with a lasting benefit to the men employed.

When discussing at length the conditions of mining, the unsatisfactory state of the sanitation and ventilation below

ground was commented upon. It is only now requisite to emphasise the necessity for improvement, seeing that the defects in these matters play no small part in predisposing the miners to tuberculosis. From time to time more stringent laws have been enforced to lessen the detrimental results of inadequate ventilation in workshops, gaols, and garrisons. The present excessive death rate from respiratory diseases of 204 per 10,000 miners renders it imperative that the conditions of mining at Bendigo be ameliorated.

At some stage in the history of the disease, whether early or late, a tuberculous infection is superimposed on the fibrosis of the lungs. The problem of dealing with the disease, to a large extent, is to diminish the sources of possible infection and to safeguard the rest of the community, or, in other words, to combat the inroads of tuberculosis amongst the people of Bendigo, with especial regard to the mining class.

The indications clearly are to prevent the spread of bacilli-laden materials from infected individuals. Foremost amongst these is the sputum which comes direct from the area of infection; and an advanced case will expectorate enormous numbers of bacilli in 24 hours; perhaps in one careless spit there are innumerable organisms. This expectoration dries, is trampled on, and pulverised, in which condition it can be disseminated by the air movements. The drying, combined with the sun's rays, kills many of the organisms, but some, at least, of the vast number daily spread broadcast in Bendigo are inhaled in a virulent form either by a healthy individual, or by a miner or other person with low resisting power. In the case of the first class, as a general rule the organisms are destroyed, but if inhaled by a susceptible person, tuberculous lung disease may be started. The more cases of phthisis and the less degree of carefulness shown in regard to the destruction of sputum, the greater will be the number of persons who become infected.

The total destruction of infected sputum is thus of paramount importance. The only certain way is by burning. Personally, I saw the spittoons wiped out with a cloth that afterwards was placed on the kitchen table, while tuberculous sputum was brought for examination in cut-glass scent bottles—the child's toy—and the patient, after having the danger explained to him, still insisted on taking the bottle away, as he said he had promised to do so. In some houses it was the daily custom to rinse the spittoon under the tap, or, as an exceptional precaution, with boiling water, and then to empty it down the drain, which, in too many cases, ended in the back yard or a neighbouring gully. Boiling water simply poured on is not sufficient to kill the tubercle bacillus, though it so damages many of them

as to inhibit their virulence. These are merely examples of daily occurrence of the carelessness and thoughtlessness, and, possibly, ignorance, in the inefficient destruction of tuberculous sputum. As these were done in the presence of a medical man, one would suspect that even more criminal negligence takes place at other times. All spluttering, also, as sneezing and coughing, by which particles of sputum are detached and ejected, it may be, several feet, is attended with imminent risk, and a protection, which may be afterwards burnt, should always be held in front of the mouth at these times.

A consumptive, therefore, does not live amongst the general community without being a source of danger to others, and every fresh case of tuberculosis, it cannot be too strongly asserted, owes its origin to some already existing case. The risk of infection may be minimised if due regard is had to the laws governing the mode of infection. There is thus urgent need for skilled attention and constant supervision. This is impracticable unless the patients are gathered together. Moreover, the admission of these patients to general hospitals, and association with other classes of sick persons, is to be deprecated. At the present time there is only one institution with wards specially set apart for the reception and care of advanced cases from the whole of Victoria. This is the Austin Hospital at Heidelberg, and the amount of good this hospital is doing in caring for advanced cases, and safeguarding the community, is inestimable. Other similar institutions should be established throughout the colony in local centres. In no place is such a need more urgent than in Bendigo.

In that city but recently the efficient laws for the removal of a leprous patient were enforced. By these laws leprosy has been almost stamped out of temperate climates; yet, to cope with tuberculosis, which is more infectious than leprosy, legislature gives little assistance. Comparing the two diseases, the infecting agent is similar—a bacillus—the modes of contraction almost identical, and in some respects the body lesions resulting resemble each other, while the measures that have eradicated one are ample to deal effectively with the other. Legislation, however, must not antecede public opinion if it is adequately to grapple with tuberculosis. Though it is but a quarter of a century since the true nature of this disease was made clear, the necessary measures for exterminating it from our midst are agreed upon. Individual action is of the utmost value, but the precautions must be universal, and when private endeavour fails public measures should assist. The various charitable institutions are doing an immense amount of good, but, from the want

of concerted action, the results are not commensurate with the efforts, and the need for a central board, systematising and supervising all efforts, is urgent. Under these conditions only will the prevalence of the disease be reduced to a minimum.

Tuberculosis is a disease affecting the whole community, and demands social remedies, and that legislation should carry out the prescriptions of science. An all-important step was taken when compulsory notification was enforced, as by it cognisance was taken of the danger of the disease to the community, but this one measure is insuffiicent. As a corollary to notification, indiscriminate spitting and carelessness in destruction of the sputum on the part of patients should be penalised. Such a law would be impracticable unless, however, the cases are under constant supervision. For this purpose consumptive homes should be provided for patients who, in the opinion of the Board of Public Health, are a menace to the community, and the length of their stay in these institutions determined by the board's decision.

While prevention of the spread of infection would thus be secured, the advanced consumptive himself would be benefited and his life prolonged. So much is this so that in a small proportion of these advanced cases the disease becomes quiescent, and, for practical purposes, cured. Certainly all early cases should be given the chance of recovery at a sanatorium. Many of these early phthisical cases are just as dangerous as the more advanced. They should be prevented from spreading infection. Thus potential consumptives will be safeguarded, and, at the same time, the best attention afforded those who have been unfortunate enough to contract the disease. No persons are more entitled to our sympathy. The best results in early cases are obtained from sanatorium treatment, combined with small doses of tuberculin. The earlier the case comes under medical observation the more satisfactory are the results.

Bendigo is particularly unfortunate in the matter of this disease. In all mining communities tuberculosis is rife, but to Bendigo the mild winter attracts many cases from other parts of the State in addition. Thus the overwhelming prevalence of tuberculosis in that city cannot be laid entirely at the door of its health authorities; but, all the same, it is their duty to make increased efforts to prevent its dissemination. The financial loss to the community of so many young adult lives, with the constant drain on the funds of the benefit societies, more than covers the cost of a separate home for advanced cases of consumption, and a sanatorium for the incipient ones. The hills in the vicinity of Bendigo provide ideal sites, and the climatic conditions are excellent. Provision should be made for miners and non-

miners alike, as the prevalence in either class is a source of danger to the other. With the establishment of such institutions, I feel convinced there would inevitably result a large decrease in the mortality from tuberculosis.

The support of the families of the affected men is a difficult social problem, but the removal of the helpless head will in no wise increase, but, on the contrary, will lighten the burden on the family. The keeping in a sanatorium of early cases for a short period, and sending them back to work for a lifetime, is a decided gain; and, even if a fatal termination results, the prevention of infection to others more than counterbalances the monetary loss of a few years' work, at the most, to the family of the affected individual. The same reasoning holds good in support of the prevention of tuberculous miners working underground. It is for the support of their wives and families that they work, and one cannot but admire such endeavour. The fact, however, that they are infecting their mates should deter them, and likewise influence the Government to prevent them from doing so. The few months or years of a crippled life are not to be weighed against the full term of one or more young and healthy lives.

When this was suggested before, suggestions were made that the Government should provide for disabled miners. In addition to the proposed accident fund, the institution of a fund for invalided miners comes, on investigation, within the realm of practicability, and nothing but good can result to a class who well deserve the support that would be thus meted out to them.

Another proposal that was previously put forward was the appointment of a Medical Inspector of Mines. In addition to performing the duties requiring such an officer, and set out in the preliminary report, he might attend to other matters necessary to deal adequately with the already existing disease. An institution would require a Medical Superintendent, while it would be necessary for a Government officer to examine applicants for relief before they receive benefits from the proposed accident fund.

There is thus more than work enough in the mining district for a first-class Government Medical Officer giving the whole of his time. The working of this important centre from the metropolis is injudicious. The financial gain by prolonging life would amply repay the expenditure. Dr. Norris' scheme for the appointment of district health officers receives ample justification from the needs of Bendigo, while the high mortality from tuberculosis amongst the miners makes it clear that it is necessary not only to improve the working conditions underground, but also by efficient measures to combat the inroads of the tubercle bacillus among the residents of the district.

SUMMARY AND RECOMMENDATIONS.

The excessive mortality prevailing amongst the Bendigo miners has been discussed; it is evidently owing to respiratory diseases, notably tuberculosis. Many of the men affected are young or in the prime of life. The number of fatal mining accidents is steadily diminishing, and this plainly indicates that more carefulness is being exercised to guard the life of the miner in the use of explosives, and by the aid of safety appliances. The increasing mortality from disease clearly shows that the same concern is not manifested in the maintenance of the miner's health. Not only does this matter affect the mining class, but the miners become sources of infection to the rest of the community.

Miners' phthisis is a typical example of a disease of the lungs brought about by the mechanical action merely by dust particles without absorption of them, and with no poisoning of the system. It belongs to the group of diseases, all similar in character, embraced under the term pneumoconiosis; it is, in fact, a silicosis. From the nature of the lung changes the disease tends to progress, and is never recovered from, though, with moderate fibrosis only, great improvement in the general health may render less obvious the dyspnœa due to the local disease. At first the disease is purely local in the lungs, and remains so till tuberculosis, with its specific bacillus, is superimposed, and poisons the entire body with its toxines, in addition producing alteration in the nature of the pathological change in the lungs.

From the pathology it is seen that any or all morbid lung conditions may occur, hence the symptomatology is various, but all the symptoms point to lung disease. The characteristics being the extreme dyspnœa, and that even after subsequent life on the surface, the sputum may still be bluish tinged, owing to its containing broken-down, pigmented lung tissue, and, on examination under the microscope, the angular, jagged particles of dust may be detected in exactly the same condition as when they were inhaled, possibly a score of years previously.

The popular idea is to class all lung diseases affecting the miners under the same heading, and it is not sufficiently appreciated that a man may have a chronic bronchitis, with some slight impairment of his general health, with also dyspnœa on exertion, and yet there is no resulting danger to life. With change of occupation the catarrhal symptoms lessen, and, though the dyspnœa persists, still, with the improvement in the general health, it passes almost unnoticed, and, unless it be extreme, does not hinder the carrying on of another occupation in which good health and a fair proportion of bodily energy are indispensable.

In addition, there is the other class, 47% of the living, affected miners, with similar symptoms at the onset, but their sputum contains tubercle organisms. The soluble poisons produced increase the constitutional symptoms, and the case progressively tends towards a fatal termination within a few years. The average duration of life after tuberculous infection is about five years, which is a somewhat longer period than is the case amongst non-miners.

Though only 47% of the cases are infected, all miners dying of lung complaint die of tuberculosis.

Of the causes predisposing to the bacillary infection, the irritation of, and consequent changes in, the lungs are the main ones. Minor factors, however, are the noxious fumes and defective ventilation in the mines, and unhygienic conditions on the surface. The prevalence of tuberculosis is due to the careless and imperfect destruction of infected expectoration.

From this brief but comprehensive summary of the nature and cause of the so-called "Miners' Complaint" it is evident that, though many amendments are possible, even necessary, in the existing laws, and also improvements in the management of the mines, miners have the safeguarding of their own health, to a considerable extent, under their own control. A miner's foremost consideration should be the care of his own health.

In addition to the recommendations already furnished in the preliminary report, all of which receive ample support from the nature and causes of miners' phthisis, others to cope with the already existing disease are given.

(1) Penalising carelessness in the destruction of tuberculous sputum and indiscriminate expectoration, whenever the patient is aware of the infective nature of his complaint.

(2) Establishing—

(a) A home for advanced tuberculous patients.

(b) A sanatorium for the treatment of early cases of the same disease. Both these should be established in the vicinity of Bendigo.

(3) Making provision for invalid miners. With this object the Government should reorganise and take complete control of all funds available for the relief of disabled miners, subsidising the funds so that all reasonable demands upon them may be met.

(4) Medical supervision in their own homes of all miners affected with lung complaint.

CONCLUSION.

While perusing the death registers, one was struck by the variety of terms applied to the disease, and also with the remark-

able consensus of opinions as to its tuberculoms character. The following are some of the names given by the medical men of the district:—Pulmonary Consumption, Chronic Fibroid Pulmonary Tuberculosis, Chronic Pulmonary Phthisis, Chronic Pulmonary Tuberculosis, Chronic Pneumonia (Fibrous), Chronic Phthisis, Fibroid Phthisis, Pneumonitis and Asthenia, with Chronic Phthisis Pulmonalis (Miners'), Miners' Complaint, Miners' Disease, Miners' Phthisis and Asthenia, Fibrosis of Lungs (3 years), and Pulmonary Tuberculosis (1 year), Pulmonary Fibrosis, with consolidation, and several add "Asthma" and "Hæmorrhage."

Miners' complaint was first noted in the register in 1887, and miners' disease 3 years later. These terms are altogether unscientific and of loose application. Miners' phthisis is the common term all the world over, and it seems the most appropriate. To distinguish the cases with the superimposed bacillary disease, the word tuberculous should be added in the infected cases, and the classification would then be—

(a) Miners' Phthisis.

(b) Miners' Phthisis (tuberculous).

No evidence of ankylostomiasis that is so prevalent amongst mining communities in Cornwall and Europe was found in Bendigo The intestinal parasite produces marked anæmia and asthenia just as does the tubercle bacillus, and hence the confusion in the public mind that the "miners' disease" of one community is of the same nature as the "miners' disease" of another, the unfortunate circumstance being that the same popular name is applied to each.

I greatly appreciated the courtesy extended to me by all the members of the hospital staff and the kindness of the committee in putting at my disposal a suitable room for use as a laboratory.

I also take this opportunity of recording my sincerest thanks to the trustees of the late Edward Wilson estate for their never-failing courtesy towards myself, and for the opportunity of carrying out what has proved a most interesting and instructive investigation.

Finally, I trust the conclusions arrived at after much thought will be acceptable, and the recommendations will receive the careful consideration of all interested.

I am, Sirs, your obedient servant,

WALTER SUMMONS.

Melbourne, 1906.

STILLWELL AND CO., PRINTERS, 195A COLLINS STREET, MELBOURNE.

1906.

VICTORIA.

DEPARTMENT OF MINES.

MINERS' PHTHISIS.

REPORT

ON THE

VENTILATION OF THE BENDIGO MINES

BY

WALTER SUMMONS, M.B.

ISSUED BY

W. R. ANDERSON, SECRETARY FOR MINES, UNDER THE AUTHORITY OF THE HONORABLE D. McLEOD, M.P., MINISTER OF MINES AND FORESTS.

By Authority:
J. KEMP, ACTING GOVERNMENT PRINTER, MELBOURNE.
10034.

Melbourne,
August, 1906.

The Committee of the Bendigo Hospital.

GENTLEMEN,

I have the honour to submit to you a Preliminary Report on the results of inquiries into miners' phthisis. This section of the Report deals with the ventilation of the mines.

Owing to present public agitation about this important question, it has been deemed advisable to forward this portion of the Report without delay. A further section, dealing with miners' phthisis, will be submitted at an early date.

The investigation was instituted through the sympathy and large-heartedness of the trustees of the Edward Wilson estate, and all the expenses incurred are being met by them.

This Preliminary Report embodies the results of my investigation and the opinions deduced from them. They are discussed in four divisions—

I. (*a*) Observations in the mines.
   (*b*) The condition of the miners at work.
II. Discussion of these observations.
III. The aim of ventilation and suggested standard.
IV. The advised methods of ventilation.

OBSERVATIONS IN THE MINES.

In the course of the investigation many mines were visited, and below are set out the results of my personal observations in a restricted number of the workings. These mines have not been chosen in any haphazard fashion, but as typical of the mines on the Bendigo field. Special attention was paid to the deepest mines, seeing that they better exemplify the conditions under which mining will be carried on in the near future.

The mines are arranged in the order of depth at the time of my visits.

NEW CHUM GOLD-FIELDS MINE.—12.1.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	73	45	
400 feet level	70	70	
746 feet level (in a dead end, 30 feet from shaft) ...	70	75	
885 feet level	70	95	

Remarks.—Mine opening up. 10 men employed. Not connected with neighbouring mines.

SOUTH NEW MOON MINE.—18.2.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	63	55	
580 feet level and 800 feet from shaft	80	97	
980 feet level and 390 feet from shaft	85	93	
450 feet plat	80	90	
450 feet level and 1,480 feet to end of drive from plat	84	94	
Top of rise 20 feet	85·5	96	

Remarks.—Big formations. In stopes mine does not feel oppressive, but men were perspiring freely in dead ends and rises. 140 men employed.

NORTH NEW MOON MINE.—20.2.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	86	35	
1,200 feet plat	82	80	

Remarks.—Ground moist though no actual water dripping. Shaft upeast. In no place did temperature fall below 80°. Men working—36.

FORTUNA HUSTLER'S MINE.—10.2.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	85	55	
340 feet level	79	86	
2,020 feet (bottom of shaft)	89	98	

Remarks.—At 2,020 feet level rock is dripping with water, and at 340 feet level air comes in from adjoining mine. Shaft upeast. Men employed—26.

SUFFOLK UNITED MINE.—9.6.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	42·5	65	
1,674 feet plat	68	95	
Cross-cut 75 feet and drive 220 feet	77	97	
Rise of 70 feet from near end of cross-cut ...	85·5	93	
Same after jet of air	77·5	90	
Rise of 15 feet and at blind top	85	97	·465
Same after three hours' use of a spray of air and water	76	95	·165
End of cross-cut 75 feet from plat	77	93	

Remarks.—Shaft downcast. Men employed—20. Shows high percentage of CO_2 in rise and great decrease with lowering of temperature after use of a spray of water and air—both at high pressure—the so-called atomizer.

NEW ARGUS MINE.—10.6.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	49	80	
1,680 feet plat	64	90	
1,780 feet plat	64	88	
At end of 100 feet cross-cut	77	85	·274
1,980 feet plat	68	94	
180 feet along cross-cut to foot of rise	77	93	
Top of 86 feet rise	85	95	·343

Remarks.—Shaft downcast. Sample of air in cross-cut was taken five minutes after firing, and there was much smoke and dust. In top of rise there was the normal amount of CO_2 in the mine air. Men employed—65.

GARIBALDI MINE.—10.3.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	66	70	
1,700 feet plat	80	97	
Dead end of drive 425 feet from plat	84	95	

Remarks.—2 men working at end of drive had pulse rates 88 and 104 respectively.

HORWOOD'S AND BURROWES' UNITED MINE —15.1.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	78	50	
2,130 feet plat	82	95	
2,060 feet plat (intermediate level)	89	97	
2,030 feet and top of rise 55 feet	92	95	

Remarks.—12 men employed.

GREAT NORTHERN MINE.—15.2.06.—First Visit.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	88	60	
1,880 feet plat	84	82	
240 feet west and 1,100 feet north of shaft to end of drive	89	90	
20 feet rise at top	95	90	
End of drive to Virginia Mine border	85	92	
1,830 feet level (intermediate)	86	93	

Remarks.—Two other visits were paid this mine, with the object of examining the men actually at work, and to estimate amount of dust in the air. Men employed—110. For the results of the medical examinations, see pages 27, 28.

GARDEN GULLY UNITED MINE.—4.5.06.

Locality.	Temperature.	Per cent. of watery vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	43	85	
1,270 feet plat.	71	98	
48 feet down ladder to stope	79	95	
Opposite end of stope, 150 feet long*	77	93	·14
1,500 feet level	78	92	
2,650 feet plat.	78	93	
310 feet along drive	87	85	·25

* The two men working here were examined.

Remarks.—Connected with South Garden Gully Mine at 1,500 feet. Shaft downcast.

Respiration, 20 per minute. Pulse, 120 per minute. Temperature, 99·8° Fah.
,, 24 ,, ,, 116 ,, ,, 99· ,,

GREAT SOUTHERN GARDEN GULLY MINE.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	80	83	
2,110 feet plat	86	96	
End of 270 feet drive	91	98	

Remarks.—Shaft downcast. 24 men employed.

UNITY MINE.—14.5.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	42	76	
2,338 feet plat	77	97	·14
At boundary of Carlisle Mine, but 1,030 feet from its shaft, which is downcast	82	95	·163

Remarks.—Shaft upcast, and 2,338 feet level is connected by a horizontal drive, about 1,300 feet long, to the Carlisle shaft, which is downcast. Men employed, 17.

HERCULES AND ENERGETIC MINE.—11.5.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	50	80	
480 feet level	75	85	
In drive 200 feet from shaft	77	85	·35
Intermediate level (500 feet), used as "crib" place	77	85	·46
2,666 feet plat	86	98	·12
End of 100 feet drive	90	98	·18

Remarks.—In the place used for the men's crib there was a marked mouldy smell, and much waste decaying food lying about. Shaft upcast.

Victoria Consols Mine.—11.1.06.

Locality.	Temperature.	Per cent of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	66	40	
2,884 feet level	82	90	
End of 346 feet drive	85	92	

Great Central Victoria Mine.—11.1.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
2,800 feet plat, connected with last mine	75	77	

Remarks.—Great Central Victoria is the downcast, while the Victoria Consols is the upcast. These shafts are connected along the 2,800 feet level.

Princess Dagmar Mine.—23.2.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	70	55	
2,235 feet plat	83	97	
Down winze and along a stope 200 feet from shaft	93	94	
3,000 feet plat	90	88	

Remarks.—Shaft upcast. Men employed, 20.

North Johnson's Mine.—16.2.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	87	30	
543 feet level	80	83	
2,845 feet plat	89	80	
100 feet cross-cut and 134 feet north in drive ...	98	85	
3,080 feet plat	92	90	

Lansell's 180 Mine.—2.7.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	50	82	
3,300 feet plat	82	95	·12
Stope 300 feet from plat and 600 feet from Victoria Quartz shaft, which supplies the air ...	83	92	
Air coming from Victoria Quartz Mine	81	90	

Remarks.—Shaft upcast, connected with Victoria Quartz at 3,280 feet level (see diagram of connexions elsewhere).

Victoria Quartz Mine.—14.6.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	42	87	
4,024 feet plat	75	98	·102
4,254 feet plat*	87	98	·212
Another visit—10.1.06.			
Surface	83	50	
3,824 feet plat	76	94	
4,040 feet bottom of shaft*	88	94	

*At present the operations consist in sinking the shaft.

Remarks.—The mine was visited on two other occasions for the purpose of examining the men at these depths. See page 28.

On the first visit about midsummer, and at the second visit in the depth of winter, the difference in temperature at the surface on these days was over 40 degrees, whereas the temperature of the mine was practically the same at every visit. The shaft is downcast.

New Chum Railway Mine.—7.1.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	80	50	
3,856 feet plat	90	95	
4,069 feet bottom of shaft	94	99	
Another visit—11.6.06.			
Surface	62	74	
3,856 feet plat	92	97	·139
4,236 feet bottom of shaft	95	99	·203

Remarks.—This mine was also visited on other occasions, and the readings were practically the same. At present the men are solely engaged in sinking the shaft. The conditions have become so oppressive that the men are only expected to work six-hour shifts. At time of visits, with shifts of eight hours below, they worked alternately for thirty minutes at a stretch, and then *spelled* for the other thirty minutes in the plat. There were 4 men and a winch-driver in each shift, making a total of 15 in all. The shaft is upcast.

In visiting some of the mines, the State Inspectors of Mines, Mr. Abraham and Mr. Hawke, accompanied me, and their special knowledge of the district enabled me to decide which were the most typical mines on the field.

I am deeply indebted to Professor Osborne, of the Melbourne University, for his careful estimation of the percentage of CO_2 present in the samples of air taken.

An Alluvial Mine.

For the purpose of making comparisons the West Berry Consols Mine, at Allendale, was visited, through the courtesy of the manager, Mr. Squire. It is a fair type of an Alluvial Gold Mine, and is ventilated by a pair of No. 4 Roots' blowers, from which the air is conducted down the shaft and

along the 420 feet level to where the men are working, 5,310 feet from the shaft. The pipes in use are 16 inches for the shaft, and for about 4,400 feet along the level. Thence the main pipe divides into three pipes, each $11\frac{1}{4}$ inches in diameter, for the supply of three sets of men. That size of pipe, continuing to the furthest point of the mine, supplies air to two men working in a rise 5,310 feet from the shaft, or nearly 6,000 feet from the blowers. The other two pipes branch off and supply two gangs of men working on the wash. These pipes are again subdivided into distributing 8-inch pipes at the faces. The air current issuing from these latter is just sufficient to deflect the light of a candle, whilst that from the terminal 11-inch pipe easily blows the light out.

Readings taken in the Mine.—27.6.06.

Locality.	Temperature.	Per cent. of Watery Vapour.	CO_2 per cent.
	Deg. Fah.		
Surface	38	54	
420 feet plat	64·5	95	·524
2,000 feet from shaft	72·5	96	
5,210 feet from shaft	71	93	
At top of rise of 43 feet	73	82	·132
Air issuing from pipe	71	46	
Second rise (4,230 feet from shaft), up 43 feet, and 600 feet from top of rise to face	72	87	

The shaft serves as the upcast for the air-pipes which are the inlet of air to the mine, and air taken from the 420 feet plat, which showed ·524 per cent. of carbonic acid gas, is a mixture of all that circulating throughout the mine. The temperature is lowered from its proximity to the shaft, but throughout the remainder of the mine the temperature is markedly constant. The workings are wet, and there can be no possibility of dust arising from shovelling and similar operations. On the other hand, the ground gives off a large quantity of carbonic acid gas, the amount depending mostly on the surface weather. This is easily to be understood when it is considered that the wash-dirt is an old river-bed. Intermingled amongst the pebbles and drift was a large amount of organic matter, which, by a slow process of oxidation, had been subsequently converted into water and carbonic acid gas. These substances were kept pent up by the basaltic stratum till the opening up of the ground.

The mining operations in an alluvial mine are necessarily all on one level, and hence the comparative facility with which artificial ventilation can be carried out.

Quartz Mines.

In the Bendigo quartz mines, on the other hand, the country rock for the most part is dry and hard. Notwithstanding this, however, in a few of the mines, notably the Fortuna Hustler's and the two deepest mines—the Victoria Quartz and the New Chum Railway—a moderate quantity of water filters through the rock. From this it might be conjectured that at greater depths than those at present reached the ground is so moist that there will result no more trouble from dust. Further, it may be surmised that, though the nature of the country remains unchanged as the shafts go down deeper and deeper, other difficulties may occur which will have the effect of limiting the extent to which the quest for the precious metal may be carried.

The silurian strata undulate from east to west, and at the summit of these undulations there are, as it were, splits, which may be compared to the

incomplete breaking of a green stick. In these crevices there has been deposited the quartz that now forms the reefs, and in some of these, to a varying degree, gold was deposited. Again, referring to the bent green stick, in addition to the cavity caused by the breaking of the stick at the top, from the break there are continued down towards both ends fissures, so that the open space enclosed by the broken stick is in the shape of an arched body, with two tapering projections downwards, and an open gap at the summit. At some time the silurian strata were upheaved, and in the spaces so formed quartz was deposited in the shape of a saddle, with two legs tapering away

PORTION OF WEST LEG OF A SADDLE REEF.
From photo. by E. J. Dunn, F.G.S., Director of Mining.

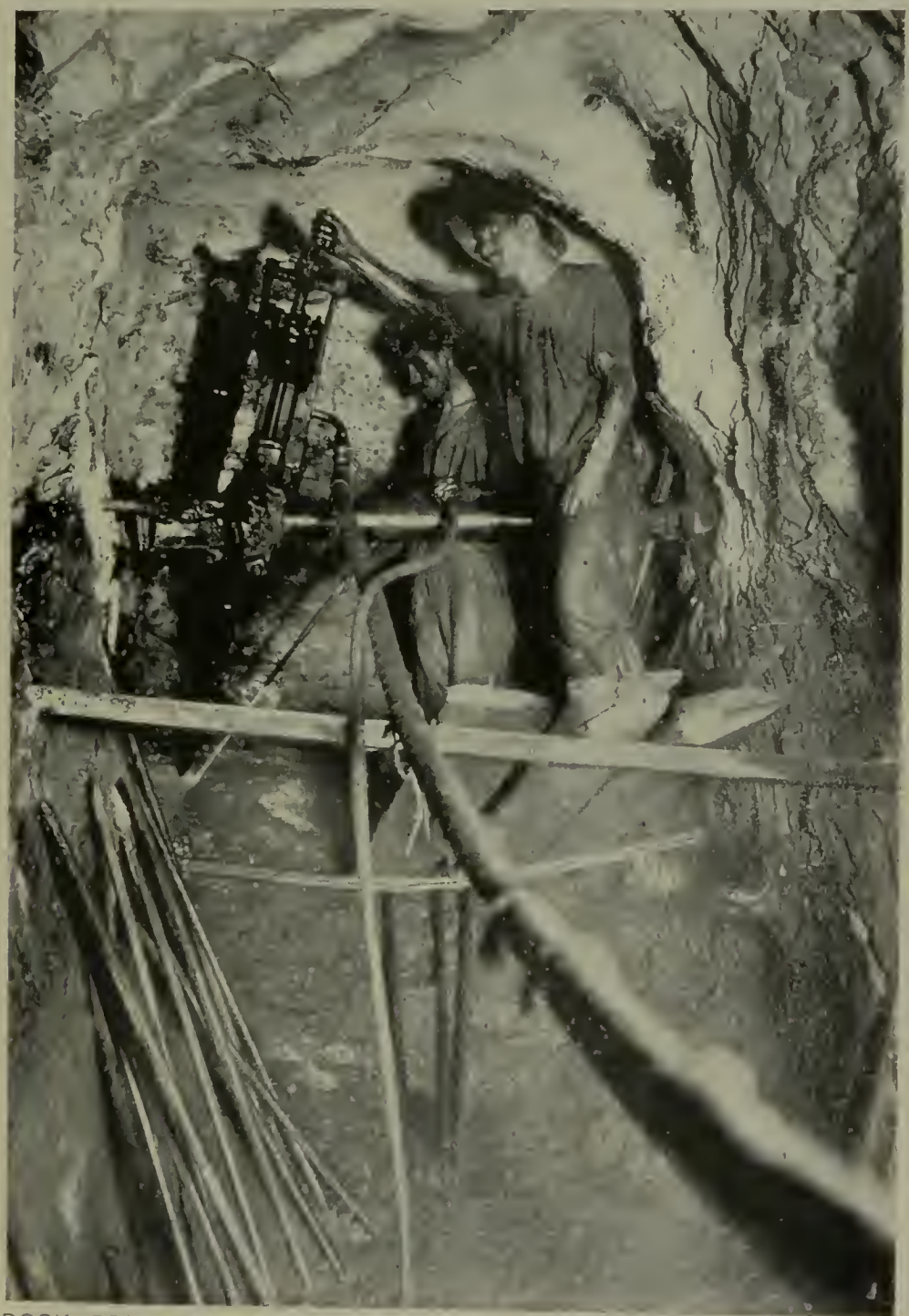
SADDLE REEF SHOWING TURNOVER, PROLONGATION UPWARDS INTO A NECK AND BEGINNINGS OF THE TWO LEGS DOWNWARDS.

From photo. by E. J. Dunn, F.G.S.

SADDLE REEF. NEW CHUM LINE OF REEF.
From photo. by E. J. Dunn, F.G.S.

east and west for, perhaps, several hundreds of feet, and also on the top of the saddle there is a projection upwards called the neck.

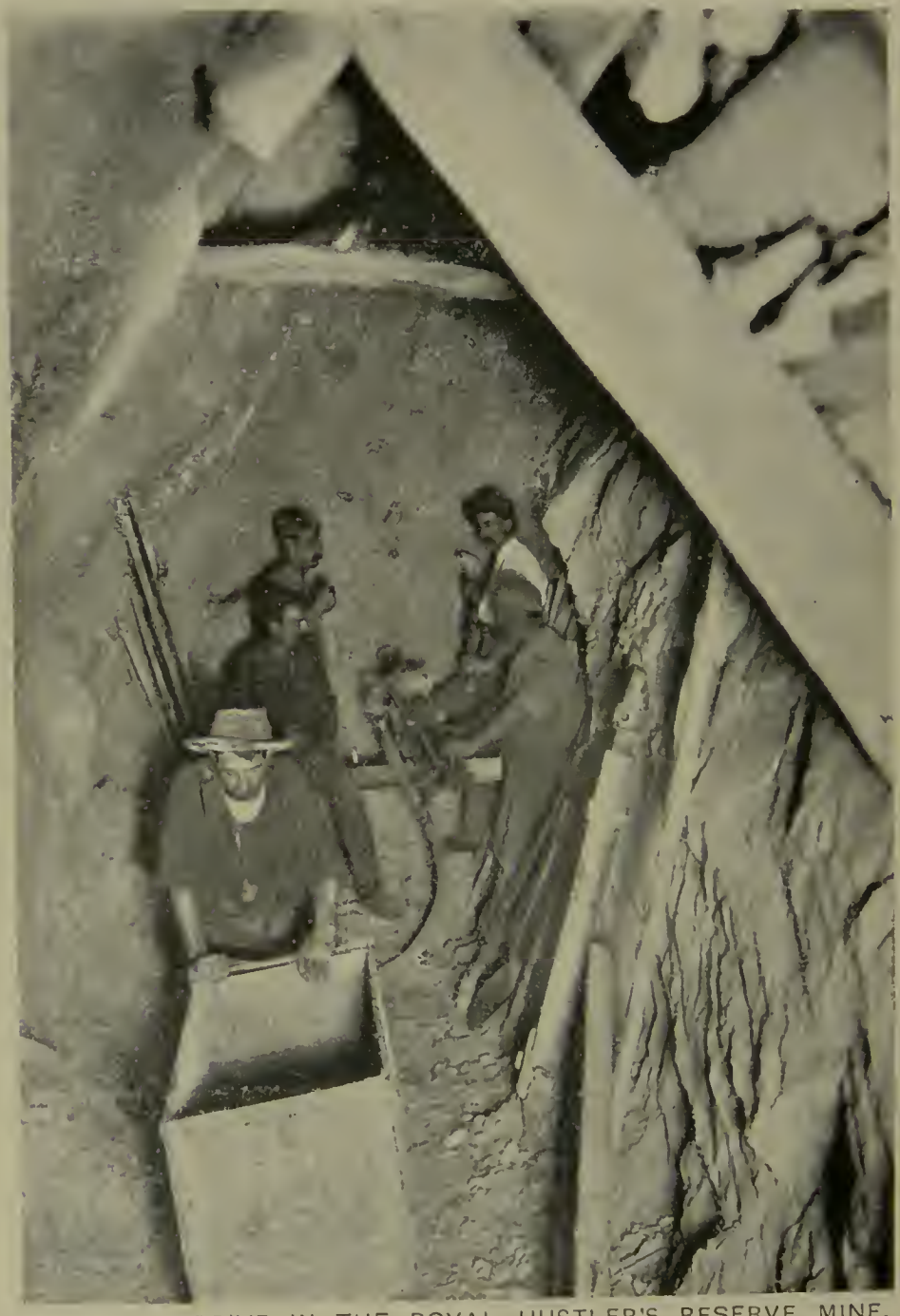
The saddle reefs are thus formed at the turn over of the strata, or in what is called the "centre country." They occur one above the other at varying intervals, and as far as may be seen in the mines as yet there is no change in the nature of the formations, so that a long life has been prophesied for the



ROCK DRILL WITH WATER JET AT NORTH JOHNSTON Q.M. CO.
BEGINNING OF A CROSSCUT.

Photo. by W. H. Robinson, Bendigo.

gold-field. From the knowledge already gathered of the district, there is work for at least 50 years to come. The richest reefs were found near the surface, though the new ones that are continually being discovered often bear good payable gold. Thus, in any proposed system of ventilation, regard should be had to the future as well as to the present, or else a time may come when, under the existing conditions, it will be impossible to continue sinking.



END OF A DRIVE IN THE ROYAL HUSTLER'S RESERVE MINE.
Photo by W. H. Robinson, Bendigo.

The sole idea, I fear, in too many minds, is to secure the gold without regard for anything else.

The main body of reef is frequently many feet through, and, subsequently to making a cross-cut from the shaft, and a drive at right angles to this, so as to strike the reef, the workings may open out into the stopes, where there may be half-a-dozen or more pairs of men at work with the rock drills, each pair by

MASSIVE SPUR (IRREGULAR FORMATION) ON THE CATHERINE REEF, WORKED BY STOPING.
Photo. by W. H. Robinson, Bendigo.

themselves and away from the others. Some at one portion of the body, others elsewhere, and others again engaged on the legs. The reefs are nearly always worked from below, so that no dirt is lifted except up the shaft. All is thrown to the level below by shoots, and thence trucked to the shaft. In addition to these men, there will most likely be others scattered about in various parts, probably on different levels driving cross-cuts, winzes, or rises for prospecting purposes, or to connect with higher levels to secure better ventilation. In all

ROCK DRILL AT WORK ON A LEG.
Photo. by W. H. Robinson, Bendigo.

parts of the mine will be found percussion machine drills, worked by compressed air. Hand drills are only used in a few of the shallower mines. As contrasted with the one level in the alluvial mine, at Bendigo the reefs are ranged one above the other, so that in many mines there are 30 or more different plats from which levels have been carried. Thus from the exigencies of the work it is extremely difficult to secure good air for all the men at a reasonable expenditure.

Of all the operations below that of rising is considered the most hazardous to health by the miners. Here the holes are always drilled upward, and the men work in a cloud of dust continually—the only ventilation frequently being the exhaust air from the rock drill. In some mines the managers supply artificial means to ameliorate the conditions, and to secure sufficient ventilation.

In the two rises from which samples of air for analysis were taken the percentage of carbonic acid gas was ·465 and ·343 in the Suffolk United and New Argus mines respectively. In both of these rises the temperature was 85° Fah., and the percentage of watery vapour was 95 per cent. of saturation. In the rise in the New Argus Mine the men refused to work; but the conditions, however, were not more oppressive there than had been observed elsewhere.

That artificial aids to ventilation are advantageous can easily be shown. Through the courtesy of Mr. William Davey, manager of the Suffolk United mine, I was enabled to take records of the improved conditions resulting whilst a spray of compressed air and water from the atomizer was allowed to play up the rise from its foot. The temperature was lowered from 85° Fah. to 77° Fah., which was that of the drive below, while at the same time the percentage of carbonic acid was reduced from ·465 to ·165, or to almost one-third of the former amount. These results were obtained under ordinary working conditions, and could, with the exercise of special care, have been made more marked. Without the artificial means the top felt oppressive, and the men were faint and perspiring freely, whereas with the spray in use the heavy feeling passed away and the men moved about with more life and vigour; the men remarking how marked was the difference. Another advantage in the use of the atomizer was that all dust was prevented. This apparatus, Mr. Davey stated, would, if properly arranged, send a spray 50 feet, and its effects could be felt as a current of air 30 feet ahead of the spray along a drive or cross-cut.

In a second rise on the same level similar results were secured by the aid of a fine jet of compressed air arranged as an air ejector into a 3-inch iron pipe. With only a small quantity of compressed air, the force produced by its escaping from a fine hole was sufficient to suck up a large supply of cooler air from the level to the top of the rise, 70 feet up, and to cause a strong current. The suction power of the air jet was amply demonstrated by pieces of quartz of the size of a hen's egg being suspended in mid air after placing them at the lower opening of the 3-inch pipe.

The following extracts from a letter from Mr. Davey will be of interest:—

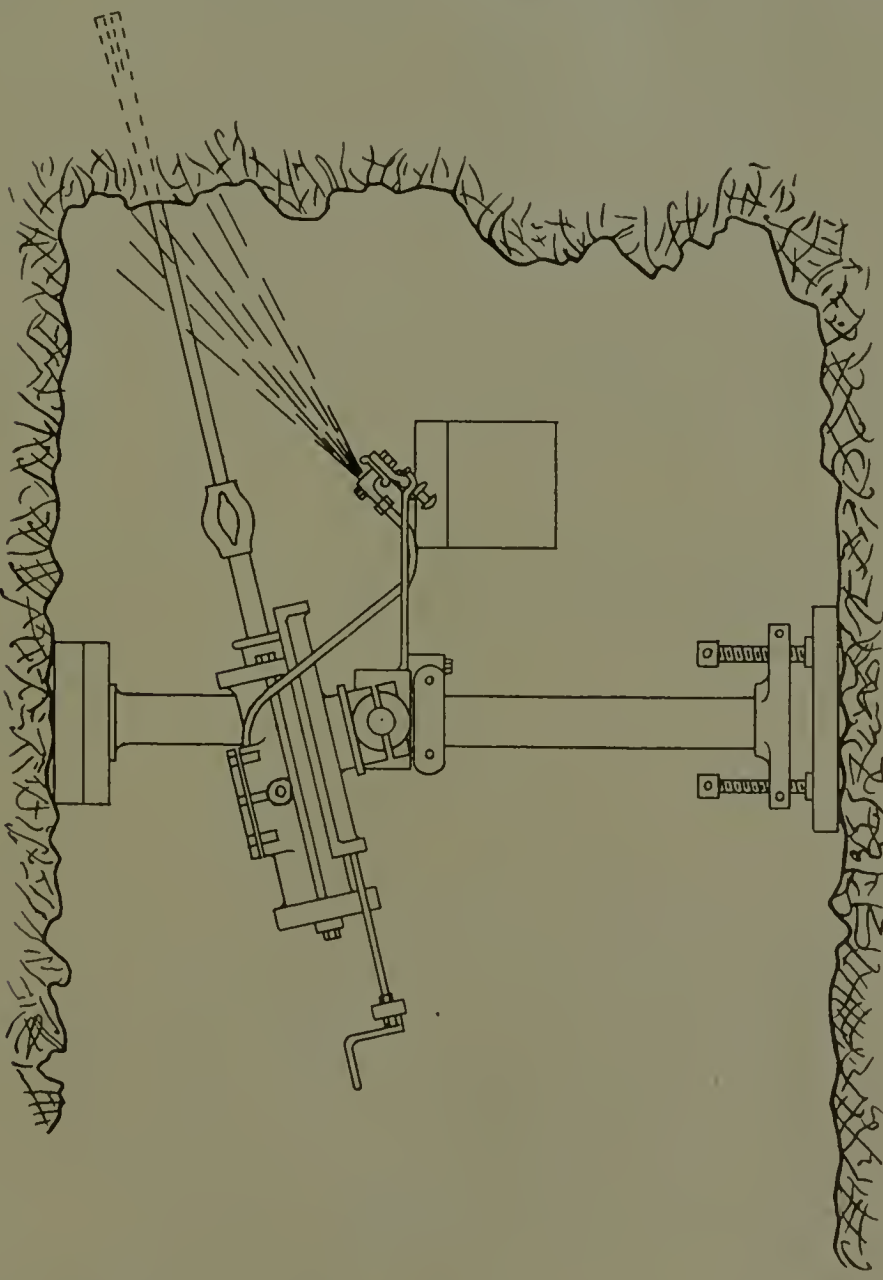
> "I find the air consumption by a rock-drilling machine to vary from 10 to 20 cubic feet per hour according to the class of machine used, and size of the air pipes for conveying the air from receiver to the working face. A fair average in this district would be 15 cubic feet."
>
> "The vacuum air blowing apparatus of ours, when tried as requested by you, reduced the pressure in the receiver from 92 to 66 lbs. in half-an-hour with full blast on. The atomizer test followed and reduced the pressure from 66 to 45 lbs. in the same time. During both tests the air compressor was not working."

Atomizer placed back from face of drive for safety.

Air main open blowing gases and fumes through Atomizer spray.

Showing Atomizer in use when blasting, allaying dust and to neutralize and allay fumes and gases.

The results obtained with this simple apparatus can no doubt be brought about by other similar means. With the use, however, of artificial appliances every care must be taken that the supply of air forced in is not vitiated to begin with, for then there would simply be an air current, while the ventilation would still be faulty. The mere result of moving the air renders blind ends less oppressive, and men working in these places are able to do so with greater energy. In many mines whose workings are below the level at which connexion with an adjoining mine has been made the only air movements

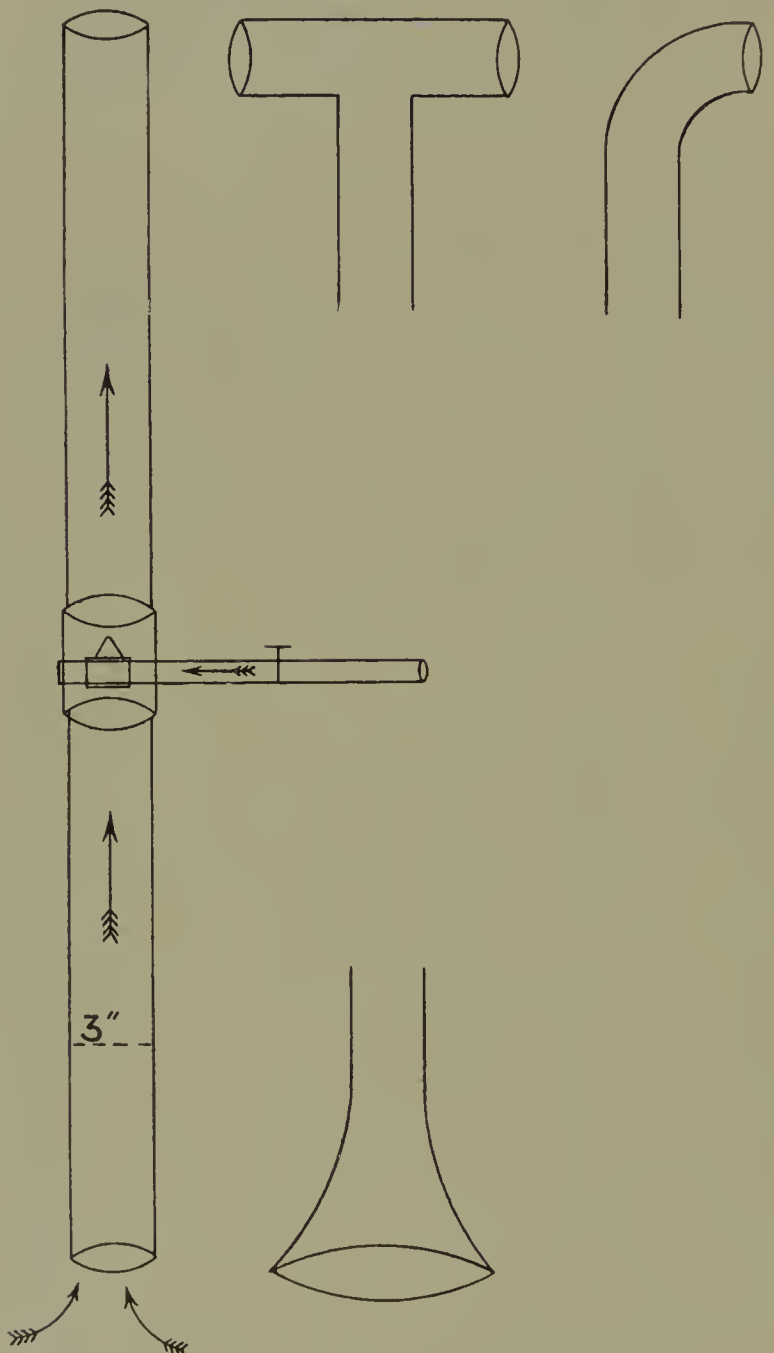


"Britten's" Atomizer in operation when drilling dry holes.

are those produced by the cage going up and down, and to a large extent the same air circulates up and down the shaft again and again. In mines such as these the ventilation is, as might be expected, markedly defective. For example, in the New Chum Railway Mine, air from the 3,856 feet plat contained ·139 per cent. of carbonic acid, while a sample from the bottom of the shaft, 4,236 feet down, showed ·203 per cent. These are the only two places in the mine where the men are at present working. In this mine, at times of visit, the men went down for eight hours, but only worked in the shaft thirty

minutes at a time, while the second pair were "*cooling*" in the plat, since then the men work in shifts of only six hours.

Examination of the men in the 3,856 feet plat at "*crib*" time (after resting) showed their pulse rates per minute to be 88, 92, 96, 104. 108, 112, and their



Compressed air ejector or "vacuum air-blower." Compressed air pipe entering vertical pipe at right angles and smaller air jet is directed along the long axis of this vertical pipe, the diameter of which is 3 inches. (Used in Suffolk United Mine.)

temperature (as shown by that of their urine) to be 101°, 100·7°, 100·5°, 100°, 99·2°, while my own rose from normal 98·4 F. to 99·5° in thirty minutes, taking no exercise whatever in that time. Here the ground was wet and the air practically saturated with watery vapour, while the temperature

of the plat was 90°, and that of the bottom of the shaft was 95°. One great redeeming feature of this mine is the absence of dust. The men were sallow and sickly looking; while from out of the few men employed in it during my six months' investigation I examined two and both were tuberculous, their sputum teeming with tubercle bacilli.

In this case neglect of carrying down winzes along with the shaft has had, no doubt, a good deal to do with the defective ventilation, and now it is the intention to sink the shaft 4,300 feet, that is nearly 450 feet from the plat before another cross-cut is driven. While sinking, three legs of hitherto unknown reefs were intersected, which might have been worth prospecting, from a financial point of view, with the aid of cross-cuts and winzes, quite apart from the necessity of carrying on this work for the sake of ventilation.

In the Hercules and Energetic Mine the amount of carbonic acid in a drive at a depth of 480 feet, and at a distance of 200 feet from the shaft was found to be ·35 per cent., and in the intermediate 500-feet level—not directly connected with the shaft—the percentage was ·46. In this latter level the men were accustomed to eat their crib and much waste food was carelessly thrown about, even though the manager had provided a box for its reception. The bread was mouldy and rotten, giving a musty, sickening odour to the place. The large percentage of carbonic acid gas resulted to a certain extent from the decaying matter, but to a greater degree it was due to insufficient ventilation.

VITIATION OF THE AIR.

Of the samples of normal mine air taken from places other than rises where the men were employed, the percentages of carbonic acid gas were ·46, ·35, ·274, ·212, ·203, ·25, ·18, ·165, ·163, ·14, ·139, ·12, ·102, and from the two rises ·465 and ·343. The sources of this vitiation of the air are partly the same, viz.:—(1) products of respiration, (2) products of combustion; with the addition of others non-existent in factories—

(3) decomposition of organic matter.
(4) results of blasting.
(5) oxidation of mineral matter.

The further consideration of each separate source in detail is to a large degree unnecessary, seeing that the gases formed from explosions have been fully reported on in several mining communities, and in Bendigo itself this subject has received attention. Reference may be had to the Report of the Royal Commission appointed to investigate the ventilation and sanitation of mines in Western Australia of February, 1905. A recapitulation of the main facts seems sufficient to meet the requirements of the present investigation. On no account, however, must it be thought that this vitiation of the air may be disregarded while making provisions for improvements in ventilation.

In discussing the sources of carbonic acid gas in air, it is customary to consider that of organic origin separately from that derived from inorganic materials. Carbonic acid by itself has little injurious effects, and its mere presence may be no indication of the state of ventilation. The actual determination of the source of the carbonic acid gas is thus seen to be of great importance. In some mines it is not possible to determine how much is derived from the inorganic sources. From the nature of the rock we can learn much on this point. In Bendigo the country rock is solid Silurian, and there is no gas pent up in the crevices, and as well there are no metallic ores containing carbon which by oxidation can be converted into carbonic acid. Thus it is evident that the amount from this source may be neglected. The exposed rock surface undergoes with process of time slight change in colour, showing that it is oxidized to some extent. In mines of other districts this

source must be regarded as a serious factor, inasmuch as it is frequently associated with the escape of volatile hydrocarbons as well.

In the Bendigo mines the carbonic acid gas is derived from sources that pollute the atmosphere in other ways as well, and the whole amount contained in the air may be considered as being the respiratory impurity for ventilation purposes. To confirm this view it was found that the gas is present in maximum amount where the men are working, notably in rises in which the percentage may be three times the amount in the drive below. If the rock alone supplied the gas the amounts would show no appreciable difference. Unless continually generated in these places, being a heavy gas it would fall to the foot and gradually diffuse itself along the level.

In all the mines the orthodox candle is in use, with kerosene lamps in the plats. This and the impurity resulting from respiration are closely associated, and are of course present in surface workshops. Underground, however, the men work in three shifts, and the pollution of the air will in consequence be continuous from both sources.

The next most important vitiation is the fumes from explosives, and from the hard nature of the rock a large amount of them has to be used. Besides carbon dioxide various products of incomplete combustion result, and this is especially the case if the charge imperfectly explodes. So far as this impurity is concerned it should be classed as above with the respiratory impurity when deciding on the limit of safety.

Other sources of vitiation to the air in the workings are emanations from the sanitary conveniences, from the bodies of men, decaying timber, waste food and moulds, fungi, &c. These furnish an appreciable amount of carbonic acid gas and ammonia, and also traces of volatile evil-smelling substances. The quantities in which they occur are too small to be dealt with by chemical analysis, but by the sense of smell their presence is clearly indicated. They no doubt materially assist in furnishing the stuffy oppressive feeling perceptible in ill-ventilated places. These reduce a solution of permanganate of potash, and thus are seen to be oxidizable. They also yield ammonia, hence containing nitrogen, and thus may be spoken of as carbo-ammoniacal substances. Also among the gases occasioned by the explosives there are some which impart to the smoke its pungency, even in the absence of any sulphurous acid or sulphuretted hydrogen.

What these are and what their exact action on the human body is it is difficult to say. Their presence is merely shown by their effects, which for the most part are transitory, and pass away when purer air is inhaled. It is almost unknown for men to be overcome and rendered unconscious by noxious fumes on the Bendigo field. Undoubtedly a man returning immediately after blasting would be so affected, but within a reasonable time the fumes become dissipated, and though the continued inhalation of them produces lowering of vitality, still they are not in sufficient quantity to occasion poisoning. The products of decaying organic matter and these fumes can only be removed by free ventilation. To a great extent the nasal and bronchial mucous membranes become tolerant of their presence, but if inhaled to any degree they produce rawness and sneezing. Thus, though a miner becomes accustomed to inhaling them, yet they continue to affect insidiously his general health just as at the same time they lower the sensitiveness of the mucous membrane.

Of these substances, those arising in the sanitary conveniences can, to a large degree, be obviated. The odours pass out into the mine workings, and though in a few cases a deodorant was at hand, it was less often made use of. Commonly the pan was put in the end of a disused cross-cut or drive, and in some mines the pan was an old tin placed several levels away; this, on inspection, was found full, with pollution of the ground around. In

other instances a satisfactory state of affairs existed — a good sanitary pan with a close-fitting lid was provided, and it was emptied at frequent intervals. To perfect the sanitation little improvement is possible without the active co-operation of the individual miner. In some cases it was obvious that this was wanting. To apply a term used by one of the inspectors of mines, these places, from neglect and carelessness, were in some cases filthy.

PARTICULATE IMPURITIES.

These may be either—

(1) Inorganic substances.
(2) Organic matter.

The solid particles suspended in the air are commonly spoken of as dust, and in the mines it consists chiefly of small particles of silica arising from the various mining operations. Foremost amongst these are rock-drilling, blasting, shovelling, and shooting the mullock and quartz down passes. One or other of these operations is being performed every few feet, hence it can be easily seen that the air in mines contains myriads of dust particles. So much is this the case that the lights any distance away appear dimmed as if seen through a fog. The fragments of rock thrown into the air may be classed as macroscopic or microscopic. The former, those seen by the naked eye, fall to the bottom within a short time. The smaller ones, however, are, if from quartz, very flaky, and float about in the air for some time, and as fresh particles are continually being thrown off, the air becomes always charged with them. It is especially in cul-de-sacs, as rises, winzes, and ends of drives, that the amount of dust is most concentrated.

With the aid of a dust counting machine, kindly lent by Professor Masson, of the Melbourne University, estimations of the number of particles were performed.

The results are :—

Lansell's 180 Mine.

3,300-feet level—Dust counter placed 3 feet from a rock drill and 8 feet from the face. No water jet being used.—Number of particles, 700,000 per c.c.

Air in stope same level. No water spray or jet used. Two rock drills working at either end, and two boys shovelling and trucking in stope.—Number of particles, 560,000 per c.c.

Great Northern Mine.

1,780-feet level—Rock drill working at end of drive. No water jet used. Counting machine 6 feet from face. Number of particles, 800,000 per c.c.

With water jet playing along drive but not directed on the drill hole.—Number of particles, 350,000 per c.c.

Suffolk United Mine.

1,674-feet level—275 feet from plat. Rock drill working in rise with no water spray.—Number of particles, 650,000 per c.c.

Similar conditions with spray of air and water.—Number of particles, 85,000 per c.c.

In drive workings wet with water spray.—Number of particles, 70,000 per c.c.

City air varies greatly as to the amount of dust, but the maximum number would never be as great as that in the neighbourhood of a rock drill with no preventive means being taken. Particles are microscopic, and are comparable to those that can be seen in a room lit by a ray of sunshine. With a water jet directed to the orifice of the hole no dust can escape, but some particles still float about when a spray is directed near, but not at the drill

hole. A water-drill should fulfil all that is requisite in this direction, but not one was found working in any of the mines visited.

No count was performed directly after blasting, as the dust then comes away in a thick cloud mixed with the smoke, rendering it impossible to form anything like a correct estimate of the number of particles. The air in and near large centres of population contains a variable amount of dust, and in this case the air most contaminated is only breathed for a short period, whereas the miners are breathing the impure air, laden with particles, for eight hours at a stretch. Another point of difference is that finely divided particles from chimneys and other sources are carbonaceous and almost inert when breathed.

Sketch of dust produced by rock drilling. Highly magnified.

Dust from a quartz mine, on the contrary, is almost totally mineral, and when examined microscopically gives different appearances. From the accompanying sketch the innumerable jags and sharp edges can be seen, which, when inhaled, cut like knives and irritate the lung tissues. In all sections of lungs from miners the particles are found in innumerable numbers, enclosed by fibrous tissue, of which their presence has caused the formation.

Of the organic particles, the carbonaceous ones may be passed over with brief comment. They produce only a slight degree of fibrosis when inhaled. Their action is analogous but they are much less irritating than the siliceous particles. Coal miners and lumpers are not so subject to lung diseases as metalliferous miners are.

From the examination of sick miners it was found that the Tubercle Bacillus played a prominent part in their complaints. A fair number of these miners were still working, or had only recently ceased work, and intended to return as soon as the state of their health permitted. Seeing this to be the case, I considered it advisable to test the mine air for the Tubercle germ. For this purpose guinea pigs, owing to their great susceptibilty to infection by this organism, were placed below in the air the men breathed. A couple of these animals were placed in each of the following mines—Ironbark, Hercules and Energetic, Koch's Pioneer, Windmill Hill, and Lansell's Sandhurst. They were below continuously from nine to twelve weeks. On examination no tubercular foci were discovered, but their lungs were pigmented in patches from inhaled dust even in this short period.

Notwithstanding these results the probabilities are that infection from man to man does take place in the workings. Many men suffering from pulmonary consumption work below, and men known to have bacilli in their sputum have been observed spitting about indiscriminately. The men work in pairs and to carry on conversation with a mate while the rock drill is working it is necessary to shout close up to the other man. Hence if one is affected the other runs a great risk of infection. Persons breathing quietly do not give off bacteria-laden particles of sputum, but during coughing or talking small particles of saliva break off and are projected some dis-

tance. These minute portions of sputum, though only held in suspension a little while, may still contain vast numbers of the bacilli; thus the opportunities are great for lungs already damaged by dust to become infected with tuberculosis. In favour of this view, men were examined who stated that their mates were likewise not in good health, and in several instances both were found to be suffering from tuberculosis. The tests with the guinea pigs, though not proving anything positively, cannot be taken as sufficient to decide that infective particles are not floating about in the mine air.

HUMIDITY.

Moisture in the air is, as a rule, not looked upon as an impurity, but a humid atmosphere, combined with high temperatures, though not an actual source of disease, has decidedly enervating effects. For a healthy life it is most important to keep the skin dry and comparatively cool, but with an air saturated with watery vapour (as the air in many of the mines is) this is not practicable. On this account the employment of water jets to prevent dust has been objected to. Moisture in the air appears much the less of the two evils, for dust more quickly incapacitates a man from work, whereas men living in tropical climates, which are comparable to the conditions below, maintain their health for many years.

The air is found to contain a large percentage of humidity again and again where rock drills are being used without water jets, even when the surroundings of the mine are such as cause it to be termed a dry mine. Also heated air holds in a gaseous form much more water than cool air, but the rate of evaporation depends on the amount of saturation. The circulation of a current of dry air on the other hand will reduce the humidity of a mine, and, moreover, will promote evaporation from the miners' bodies, thereby having a cooling effect. By proper ventilation the ill effects of humidity may be minimized, and thus the argument against the use of water to prevent dust should carry little weight.

TEMPERATURE.

In addition to actual impurities, the mine air possesses other peculiarities detrimental to health. The most important are its high temperatures and stagnation due to the inadequate circulation.

The ways in which the heat is produced are :—

(1) Natural temperatures of the rock. When sufficiently deep, so that the variations produced by the irregularities of the earth's surface and the weather changes may be neglected, the temperature of the rock apparently increases regularly as the depth. No accurate determination of this has been published, but for practical purposes, as far as it influences the temperatures of the mines, the increase may be taken as 1deg. F. for about every 70 feet. It is conceivable, moreover, that as the depth increases the mean rate of rise of temperature may steadily become greater and greater. The highest reading of the thermometer was obtained at the bottom of the Victorian Quartz shaft 4,200 feet from the surface, or about 3,700 feet below sea level, where the water, probably welling up from a greater depth, issuing from a crevice in the rock, was 114deg. F. In the near future a series of observations will be taken to estimate accurately the rock temperature at Bendigo.

(2) The result of chemical action—

(*a*) From the persons present.

(*b*) From lights and explosives.

(*c*) From the exposed rock surface.

(3) The compression of the air as it descends the shaft, due to increase in the barometric pressure.

The heat produced by chemical action and lighting is far less than that radiating from the country rock, but in places as rises, whence the heated air

cannot escape, the former are factors that must not be neglected. The country rock is but scantily mineralized, and does not undergo oxidation to any appreciable extent. From the slight change in the colour, however, it is seen that some chemical processes are at work.

The temperatures of the deeper mines are higher than those of the more shallow ones, but exceptions to this rule are to be found, especially where the shaft is downcast and the air has not been in contact with the rock sufficiently long for a mean temperature to be attained. Nevertheless, when the air has travelled some distance in and around the workings a stationary temperature is ultimately reached. The readings of the thermometer obtained in the Victoria Quartz and Lansell's 180 mines clearly show this. In the former, which has the down cast shaft, the air in the 4,024 feet plat is 75° F., and, as this mine is at present engaged solely in sinking, the air goes direct to the connexion with the 180 Mine, as indicated in the sketch of these two workings. On reaching the latter mine the temperature has been raised to 81°, and by circulating through the stopes where the men are working it is further increased to 83°. On leaving these stopes the air passes along the drives and crosscut to the plat before ascending the shaft. In the plat the thermometer reads 82°, or only 1° higher than that of the air entering the workings of the 180 Mine. Where, however, there is no circulation of air, and heat is continually being produced, higher temperatures are obtained. Thus blind ends give higher readings than elsewhere on the same levels.

High temperatures are looked on by some mine managers as unavoidable, or as being one of the necessary evils of deep sinking, while others express the opinion that with efficient ventilation the temperatures of the working can be made to correspond with the variations of the air temperature above ground. In mines of any depth these surface variations do not appreciably affect the ventilation. Whatever the temperature of the surface may be, whether the time of visit is midsummer or the middle of winter, the temperatures of the mines do not vary to any appreciable extent. At deep levels air fresh from the surface has a powerful cooling effect. It withdraws more heat than it gives up, but in time a point is reached when the gain and loss counterbalance one another. Air, under increased barometric pressure, contains more heat than the same volume of the same temperature on the surface. This heated air rises and cools by expansion in the upcast shafts. As the air is almost always near the saturation point below, moisture is condensed to the form of steam in the shafts so that the air leaving is always misty.

Referring to the tables giving the percentages of watery vapour it may be seen that the air in the majority of the mines borders on saturation, and when stagnation of the air also exists save for the currents caused by the men working, and the escape of compressed air from the machines, the unpleasant effects are greatly increased. It is a matter of common observation that close days are oppressive on the surface quite apart from any contamination of the atmosphere, and no medical practitioner neglects the favorable influence on the health of his patients of cool and moving air. The results of sanatorium treatment amply illustrate this. It cannot be mere purity of air that causes the beneficial results. The most recent work in physiology goes to show that that the keeping of the skin cool and dry plays a potent part in the maintenance of health. Thus the mere circulation of air by fans, quite apart from any improvement in ventilation, would have a very beneficial effect. At all levels moving air transforms an oppressive place to one in which men can work with some degree of comfort—the more so is this the case the nearer the air is to saturation with watery vapour. The health of some miners at present working would warrant their removal to a sanatorium to enjoy the benefits of an altogether open-air life.

To the temperature and humidity combined are due the languor felt by the men at work, and also their inability to perform sustained work. Dr. Haldane experimentally determined that if the wet bulb thermometer exceeded a certain point (about 78° Fahr.) continuous hard work becomes impracticable, and beyond 88° Fahr. it is hardly possible for ordinary persons to remain for lengthy periods in such air. These figures refer to still air; in moving air the limit is extended upwards by several degrees.

Though there can be fixed a maximum point above which the temperature of the mines must not go, it is extremely difficult to decide at what temperature the detrimental effects begin. Much also depends on the amount of moisture present, and on the constantly varying air movements. As Dr. Haldane points out in the same article, in still warm air the temperature that is harmful is not that of the air, nor the degree of saturation, but the temperature shown by the wet bulb thermometer.

CONDITION OF THE MINERS AT WORK.

During the time spent in the investigation the health condition of the men was repeatedly ascertained while at work, and also on the surface for purposes of comparison. The majority of the subjects examined were strong men in the prime of life. Attention was mainly paid to respirations, pulse rates, blood pressure, body temperature, and general condition. Below are lists of some of the results of these examinations :—

GREAT NORTHERN MINE.

Men examined in the 1,830-ft. level.

—	Pulse.	Respirations.	Temperature.
E.W.T.	64 irregular and intermittent	24	99·4° Fahr.
M.	104	28	—
E.T.	76 irregular in time and volume	26	99·8°
W.R.	80	20	—
W.G.	88	24	—
M.	124	24	100·0°
L.	100	20	—
Z.	124	26	99·6°
X.	112	26	99·6°
H.	96	28	98·4°
H.	116	24	99·2°
J.T.	86	24	—
J.T.	104	28	99·0°
X.	108	22	—
W.C.	96	24	—
F.B.	96	20	—
X.	72	22	—
J.B.T.	88	24	

GREAT SOUTHERN MINE.

Men resting in drive 2,110-ft. level

	Pulse.	Respirations.	Temperature.
G.W.	108	20	—
W.H.S.	100	18	—
R.R.	108	22	100·2°
A.F.T.	124	26	99·8°
McN.	116	30	(organic disease of chest)
X.	92	24	99·6°

New Chum Railway Mine.

Surface.			3,856-ft. plat (men resting).			
Pulse.	Respirations.	Blood Pressure.	Pulse.	Respirations.	Temperature.	Blood Pressure.
					°	
68	16	120	88	20	100	126
72	18	124	116	20	99·2	132
72	18	150	104	24	101	146
76	20	136	108	22	100·5	146
			112	26	100·7	—
			92	20	—	—
			104	24	—	—
			124	26	—	—

Victoria Quartz Mine.

Surface.			Men resting in 4,024-ft. plat.		
—	Pulse.	Blood pressure.	Pulse.	Blood pressure.	Temperature.
					°
J.H.	92	130	100	130	99·6
F.S.	72	134	80	130	—
W.D.	76	124	104	134	99·5
F.T.	68	124	76	—	—
W.J.	90	126	108	144	—
E.S.	84	120	96	120	99·0
W.R.	80	124	84	124	98·8
C.	68	112	76	120	98·6
B.	72	124	104	140	—
B.	68	140	92	144	—
W.	88	136	92	130	—
M.	78	126	100	140	—
H.	72	160(?)	72	154	—

West Berry Consols Mine, Allendale.

Men Working at the Faces.

Pulse.	Temperature.	Respirations.
	Deg. Fahr.	
92	98·4	16
80	98·8	20
76	98·2	18
96	99·2	20
88	98·6	16
84	99·2	18
72	99·0	24
84	97·8	20

Respirations.—As would be expected from the amounts of carbonic acid gas detected in the analyses, no apparent difference in the respiratory rate or depth of breathing was observable from that of labourers working on the surface. It is not till the carbonic acid gas in the air breathed amounts to between 2 and 3 per cent. that there is any increase in the respiratory rate.

Till this amount is reached the extra work thrown on the lungs is accomplished by a slight increase in the depth of the respirations hardly to be observed by mere inspection. Rates of from 20 to 28 occurred when the men were working, but while resting in few cases was the respiratory rate found to be above normal, unless associated with organic disease of the lungs.

Pulse Rates and Rhythm.—Every case examined showed a definite increase in pulse rate while underground, the increase bearing a definite relationship to the rise in temperature and deficiencies of ventilation. Thus pulse rates while resting of 120 were not uncommon, and rates of over 100 were frequently observed (normal rate being between 60 and 80). In a small proportion of cases the rhythm was altered, and showed the heart beats to be irregular in time, and to vary in strength from beat to beat. As a rule, there was no alteration in the blood pressure with increase of barometric pressure. In cases, however, with increased pulse rates the blood pressure showed a corresponding rise, but, apart from this, the manometer readings were much the same as those obtained on the surface.

Temperature.—In this respect the alteration from the normal was the most constant. Comparatively few temperatures were not raised, and, again, the extent bore a definite relation to the increase in mine temperature and ventilation deficiency. Thus, in the New Chum Railway Mine, with saturated air and temperature of 95° Fahr., the men's temperatures were 101°, 100.7, 100.5, 100, 99.2, and my own, after thirty minutes, 99.5. In the Great Northern, with a mine temperature of 91° Fahr. and 90 per cent. saturation with aqueous vapour, the men's temperatures were 100°, 99.6, 99.2, 99.2, 99.0, 98.6, and my own 99.4. Similar results were obtained in other mines.

However much violent exertion a man may take his body temperature remains normal, provided the perspiration freely evaporates. This will take place in moving air. On the other hand, in stagnant saturated air, perspiration is formed, but cannot evaporate, so the skin is continually moist. This condition of the skin is not conductive to good health, and in the absence of evaporation of perspiration the body temperature must rise.

As well as these observations that can be recorded, the tired appearance and general languor of the men should be taken into consideration. In this respect a large personal factor comes in. Some men would feel tired whatever might be the surroundings in which they worked. With rare exceptions the miners are not of this class, but work with a will, and, when observed resting, as far as one can judge from appearances, there was just cause. Many have a general feeling of exhaustion and discomfort, and perspire freely, even when not performing laborious work. On the surface this tendency to free perspiration continues, and largely accounts for the statements sometimes made that miners have a peculiar odour about them, the persistence of the explosive fumes adding a distinctive smell. The pallor and sallowness of their faces can hardly be explained by the absence of sunlight, as the longest shift underground is eight hours, or one-third of the twenty-four hours.

THE AIM OF VENTILATION AND SUGGESTED STANDARD.

The question arises—What is good ventilation in places where men have to work continuously? The subject should be considered from every aspect—economic, practical, and humanitarian.

It will be readily admitted that it is not economical to have the ventilation so inadequate that men can work for only thirty minutes at a stretch, or that they can remain below only six hours, and then under conditions detrimental to their health. Taking into account the indifference

shown by some mine managers in this matter of ventilation, it is certainly preferable for the men to work a shift of six hours to one of eight hours. No monetary consideration, such as an additional 5s. a week in the wages, should carry weight when the men's health is at stake. Both of these devices have recently been in vogue. They are only makeshifts at the best, and harmful inasmuch as the time for demanding improved ventilation is, by such means, likely to be indefinitely postponed. If these are necessary now, in ten years time, when the mines may be down another thousand feet, some further concessions will have to be granted, and ultimately, if existing circumstances continue, mining operations will have to cease, the conditions becoming too oppressive, owing to the inadequacy of the ventilation. Likewise, though it is a healthy moral sign to make provision for worn-out miners, yet, if greater attention was devoted to the amelioration of the conditions under which the men work, there would be a correspondingly greater benefit to the mining community.

It is practically impossible in many mines to estimate by anemometers the fresh air that is circulating through the passages. A more satisfactory standard, and one which gives an accurate estimation of the ventilation, is the proportion of carbonic acid in the air. This gas does not show itself in immediate effects till the percentage in the air of the confined place begins to exceed 2 per cent.

In a healthy individual under normal conditions the air remaining in the lungs after a deep expiration contains from 5.5 to 6 per cent. of CO_2; hence it is not to the poisonous effects of this gas that the ill-health is due. The great use, however, that can be made of its presence is in estimating the efficacy of the ventilation, for the percentage of carbonic acid varies directly with the ventilation. The corresponding deficiency of the oxygen is not harmful of itself.

The clearest indication that insufficient provisions is made for ventilation on the Bendigo field is the prevalence of ill-health among the miners. Adequate ventilation is conducive in every way to good health.

When the sources of vitiation of the air are considered, it is evident that some are due to causes which can better be dealt with by preventive measure than by removing the contamination subsequently by efficient ventilation. Notably amongst these is dust. In this preliminary report I do not wish to enter in detail into the causes of Miners' Phthisis, but may mention that without dust inhalation there would be no lung disease peculiar to miners. With the prevention of dust, miners still would be more liable than other workers to chest diseases, especially tuberculosis. Without the dust irritating the respiratory system, chest diseases would be much less among them. Dust must be looked upon as the main source of Miners' Phthisis of a non-tuberculous type, and dust prepares the way frequently for miners to become infected with tuberculosis.

Since the start of the investigation instructions have been issued to the mining inspectors to enforce the provisions of the Mines Act with regard to the abatement of the dust nuisance in mines. The provisions relating to dust in mines are in section 45 of the Act, sub-clauses (2) and (3), and read—

> "(2) No hole shall be bored or drilled by machinery underground, unless a jet or spray of water shall be directed and kept directed into or around such hole in such a manner and to such an extent as is necessary to prevent the issue of dust from such hole during such drilling or boring operations, or unless some other means are adopted, which, in the opinion of the inspector, are sufficient to prevent any nuisance being caused by such dust . . . ."

"(3) In the event of any nuisance whatsoever being caused by dust or fumes mingling with the air in any portion of the workings of a mine in which miners are working, to such an extent as, in the opinion of the inspector of mines, to be detrimental to the health of such miners, it shall be the duty of the mine manager to remove such nuisance by spraying or other effective means."

These clauses are amply sufficient if carried out. Again and again I found the men working in a cloud of dust, though within a few feet there was a water jet available. The use of the jet causes some trouble and inconvenience, while the effects of the dust are not felt for some time. The companies may or may not be doing their best, but in the suppression of the dust the miners have in their hands, to some extent at least, the power to help themselves. As soon as they realize its disastrous effects they will not be so neglectful of the law as at present, but endeavour to obey it strictly in this matter. A water jet playing along the drive is useless. It must be "directed and kept directed into or around such hole in such a manner and to such an extent as is necessary to prevent the issue of dust." Too much emphasis cannot, I feel convinced, be laid on the dust as the main cause of the phthisis peculiar to miners. In all the operations of rock drilling, shovelling or emptying the mullock or quartz down a shoot, a spray of water should be used; and in dealing with the dust evil, it is only necessary to repeat the phrase—"Dry mining should, as far as possible, be converted into wet mining," used by a Royal Commission into Miners' Phthisis in the Transvaal.

Though dismissed with these few words, it must not be forgotten that of all the impurities the dust is the most potent factor in producing disease, and the evidence in support of this view is of the strongest character. The effects when produced in the lung are absolutely irremediable; hence the necessity for realizing its disastrous consequences. Abolition of the subsequent ills can be secured more effectively by preventive measures than by increased ventilation. This latter does deal with the nuisance to some extent by diluting the air, but it is in no way to be compared with the constant use of water jets and sprays.

The pollution of the air arising from waste crib (food) and imperfect sanitary conveniences can be better guarded against than removed. The mining inspectors at most can only visit a mine occasionally, and even then it should hardly be thought necessary for him to point out neglect in these matters. Such, however, is frequently the case. Not merely unpleasantness is thereby caused, but neglect in these matters results in a serious menace to health, and that to an even greater extent than on the surface. Many miners seem to consider neglect in this respect as unimportant—a trivial matter which does not concern them.

The place chosen for the sanitary pan should be near to the exit of air from the mine, and not, as frequently found, in the furthest position from where the men are working. In construction the simplest arrangements supply all that is needed, a cross bar and an impervious receptacle with a tight-fitting lid are ample.

The question of deodorants and antiseptics is important. As the result of visits below I have come to the conclusion that substances like lime are not permissible; these destroy the organic matter, but pollute the air with gaseous products. If, however, the gases immediately leave the mine lime would be suitable, but when this is not possible, as in a mine with a downcast shaft, the gases circulate through the adjoining one which is upcast. In this case some absorbent material would be preferable, such as charcoal (ashes) or sawdust mixed with some antiseptic. The pollution of the mine

should be made a punishable offence, and power should be vested with the inspector to inflict a small fine upon any one offending.

There is almost the same urgent need for improvement in the matter of waste portions of "crib," and the receptacles set apart for waste food should be frequently taken to the surface and emptied.

Passing on to the vitiation of the air that can only be removed by better ventilation, the question is raised—what standard must be adopted to insure that the mines are adequately ventilated? A standard based on the *quality* judged by the percentage of carbonic acid is much more satisfactory than a quantitative one, for the reasons previously given. The disadvantages of a quantity standard are obvious. Supposing the air to be pure, what need is there for a provision that 70 cubic feet of air per minute should be supplied for each man?

The standard of vitiation allowable in factories is fixed at ·12 per cent. carbonic acid. Pettenkofer, who is acknowledged to be the pioneer of hygienic science, proposed ·10 per cent., for when this standard was exceeded the air began to smell unpleasantly. Coming nearer home the Royal Commission in Western Australia, which inquired into the ventilation of mines in that State, arrived at the conclusion that ·15 per cent. was the maximum allowable impurity, and that this was a fair and easily maintained practical limit.

As before shown, the carbonic acid present in the Bendigo mines, though not altogether due to impurity from respiration, results from other causes which are as harmful. For ventilation purposes the amount may thus be considered as the "respiratory impurity," and the standard adopted should not differ in any way from that required for factories. Though ·12 per cent. is the standard generally taken, in cotton-cloth factories, in which it is desirable to have a moist atmosphere to facilitate the manufacture of the goods, a higher standard is adopted, and the law limits the amount of carbonic acid gas to ·09 per cent.

In the mines we have a warm, humid atmosphere, vitiated in more ways than that of surface buildings, containing a large amount of dust and products from combustion of explosives. It would not be asking too much if the miners were provided with the same quality of air as is insisted on in factories. However, a maximum can only be adopted that is attainable at reasonable cost. Under similar conditions in Western Australia ·15 per cent. was chosen as a satisfactory standard, and there is no reason for adopting a lower standard for the mines of Bendigo.

The present Mines Act makes no distinction between mines in which a large amount of carbonic acid is derived from the rock and others where this amount is negligible, but with regard to the quality of the air states—"The amount of carbonic anhydride in the air in any working places of the mine or in the approaches thereto shall not exceed three parts by volume in 1,000, and the amount of oxygen in the air in such working places or the approaches thereto shall not be less than twenty per centum by volume."

The New South Wales Act, on the other hand, requires that the CO_2 shall not exceed ·1 per cent., as well as saying that the supply of pure air be of not less quantity than 100 cubic feet per minute for each worker.

Adopting a quality standard, which is certainly a more rational one, the quantity of air is immaterial. Moreover, in a large open stope there may be a current sufficient to fulfil the law's requirements, but it moves so slowly that even the most delicate anemometer for practical observations may not give a true record, whereas when the stope narrows to a drive again there would be a strong current of air. I would therefore propose that ·15 per cent.

should be taken as the maximum limit of permissible carbonic acid gas in the Bendigo mines. As well as the vitiation of the air, the temperature and humidity must be considered. It has been seen that the amounts of carbonic acid found by analysis (·46, ·465, ·35, ·343, ·274, ·25, ·212, ·203, ·18, ·163, ·18, ·14, ·139, ·12, ·102) exceed this limit in the majority of cases, but the air examined was taken from cul-de-sacs, where the ventilation cannot be otherwise than bad unless artificial means are taken to improve it. No doubt, if samples were collected from where the air is entering a mine (from shaft or plats in a downcast, or from the connecting drive in an upcast mine), the percentage of carbonic acid gas would be found to be well within the standard. In the downcast shaft the amount would not be different from that normally existing in atmospheric air, namely, ·04 per cent., so that there is a margin of ·11 per cent. Though the present Act says that the air "shall be of the same purity and quality when it enters the mine as the air on the surface," the air entering the upcast mine obviously must have deteriorated to a certain extent whilst circulating through the downcast mine. Nevertheless, such a mode of ventilation is infinitely superior to propelling or driving air down from the surface. Thus the margin allowed to this second class of mines will not be as great as in the former.

Temperature.—It is not possible to decide on any maximum temperature, for this depends on irremediable and varying causes at different depths. In the Suffolk United Mine, with a downcast shaft, on the 1,674 feet level, by artificial means, the thermometer can be kept below 77° F. In the Victoria Quartz, which is also downcast, the temperature of air in the 4,024 feet plat is 75° F., and, though going straight to Lansell's 180 Mine, its temperature is raised to a few degrees over 80° F., and after circulating throughout the mine leaves it at about the same temperature. In this latter combination of mines there is a superabundance of air supply, and these temperatures must be considered the minimum possible for the depth (nearly 4,000 feet).

The course of the air is indicated by arrows in the diagram of the lower workings of these latter two mines.

Dr. Haldane has experimentally shown that 78° F. is the point which must not be exceeded in stagnant saturated air; in moving air how far the temperature consistent with continuous work may go above this depends on the movement of the air and on the amount of saturation—that is, on the temperature of the wet bulb thermometer.

By adopting ·15 per cent. as the maximum percentage of carbonic acid, this further benefit is gained that it necessitates the air constantly circulating, and thus the temperature of the wet bulb thermometer will not, except in very few instances, exceed 78° F. Nowhere at present depths will it be necessary to demand a large current of air solely to keep the temperature within workable limits.

Compressed Air.—All the rock drills and winch machines are worked by compressed air, and thus only a few of the shallow mines are without air-compressing cylinders. Amongst the miners the compressed air is not in much favour. It is considered to possess several bad properties. Many give it the appellation *light*, by which is meant that when set free into a cul-de-sac after blasting the smoke is only blown along the drive a certain distance, and there it hangs about. The air when escaping at high pressure does so noisily, especially when the exit is small, although the volume set free is not great. By a fuller supply the smoke would be driven away completely.

Others say it is harmful, without being able to state definite reasons for thinking so, apart from the fact that when inferior lubricants are used, there

may be a faint odour largely due to the presence of small particles of oil, which have been carried down, escaping with the exhaust air. It is inconceivable that the mere act of compression of air will in any way alter its composition. Professor Osborne estimated the carbonic acid in a sample of compressed air at Bendigo to be ·06 per cent. The exhaust air from a rock drill and a winch machine, however, were found to contain ·173 per cent. and ·168 per cent. of carbonic acid gas respectively. The causation of this increase requires further investigation.

The presence of oily particles can be avoided by keeping the machines clean, and especially by blowing off the receiver at frequent intervals, at least once a week. No inferior oil should be employed.

No doubt a cold blast of air, playing for any length of time, on one part of the body does harm, yet compressed air as an aid to ventilation must be considered a positive benefit.

The latent energy it possesses from its high pressure can be well utilized as mentioned before when discussing its use in the Suffolk United Mine.

THE ADVISED METHODS OF VENTILATION.

So far this preliminary report has only dealt with the results of the ventilation now in vogue and the suggested standard to be aimed at.

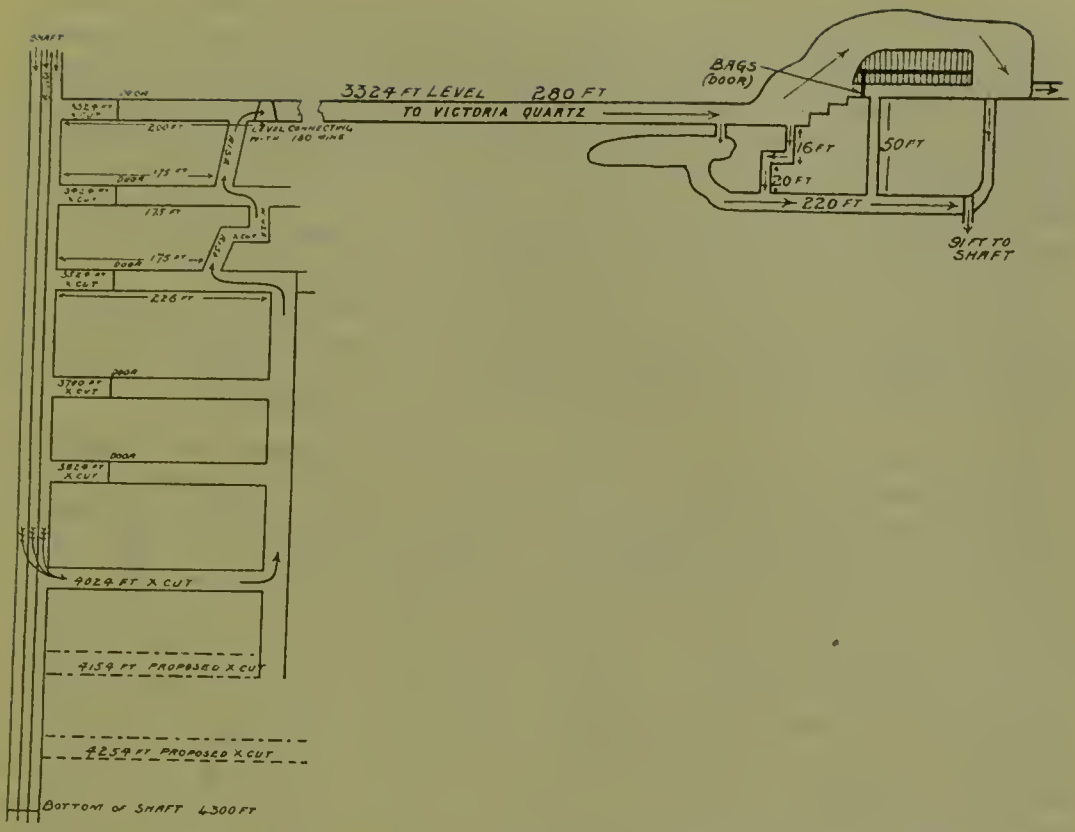
It remains to discuss briefly the means that can be adopted to ensure adequate ventilation. Only such methods will be considered as are practically attainable, and at a cost commensurate with the working of the mine. Many difficulties at once present themselves, in consequence of former neglect and want of foresight, but every reasonable endeavour should be made to overcome them.

Before discussing these means I should like to state emphatically that it is not knowledge but performance that will rectify matters. More faults are due to wilful negligence than to ignorance. Many mines are insufficiently ventilated now, not because the directors and managers do not know what to do, but because they will not on account of the expense; not considering their employés' health sufficiently—a matter which apparently does not concern them. Here it seems to me that there is great room for improvement. The Government should insist absolutely that if a company will not provide sufficient ventilation, it should not be permitted to carry on operations.

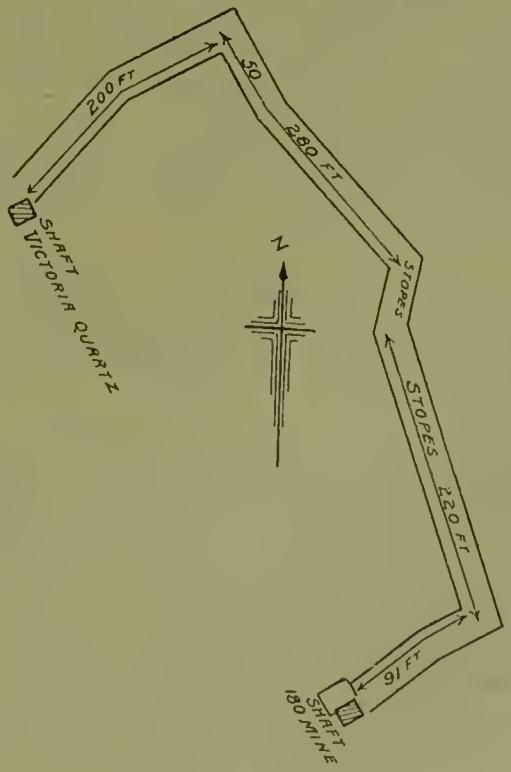
As it is not practicable to sink simultaneously two shafts on the small leases at Bendigo, saving in a few instances, the next best expedient should always be adopted, namely, that while the shaft is being sunk a winze should be carried down concurrently and connexions made between the two at regular intervals. This system by itself is not adequate unless the adjacent mines are so connected as to produce steady air currents.

To exemplify this method of "natural ventilation" the lower workings of the Victoria Quartz and Lansell's 180 mines may be again brought under notice. In the diagram the direction of the air currents is indicated by the arrow heads. The former mine is 1,000 feet below the connecting level; the air, however, now goes down to the 4,024 feet level, and when the proposed crosscuts are completed, it will circulate round the bottom level, and all the time a large supply of air goes to the 180 Mine. If this latter mine sinks deeper, with a similar system of winzes as in the quartz, good ventilation can also be carried down even without further connexions being made between the two mines. The air currents will, however, go in the reverse order—the winzes will serve as the downcast and the shaft as the upcast as it does at present.

The connexion of neighbouring mines is by no means a one-sided advantage. The mine with the down-east shaft, that is the mine down the shaft of which



Sketch of lowest level workings of Victoria Quartz and Lansell's 180 mines, Bendigo.



the air descends, is no doubt far the greater gainer, yet the upcast mine, that is the one whose shaft acts as the channel by which the air comes to the surface, is also vastly improved. Without the air current so derived the majority of the mines at Bendigo would be unworkable. This plan should be universally adopted. By this means, however, air only circulates down one shaft through the connexion, and up the other shaft. There must be also a proper distribution of the air throughout all the workings, the air always taking the shortest circuit. Hence unless there be a judicious closure of passages the air will not go through the lowest levels or those furthest away from the shaft.

Where doors are used to stop a short circuit they should be close fitting to prevent leakage, and all disused workings when not needed as airways should be totally closed. This procedure economizes and utilizes the air fully, and there is at the same time the minimum space to be ventilated.

At the present time the mines without adequate ventilation are those that have got ahead of their system of ventilation. They have neglected to carry down the winzes *pari passu* with the shaft. There is only one channel to serve both inlet and outlet, and thereby the opposing air tendencies (of the workings to ascend, and the atmospheric air to descend) are neutralized. One shaft thus will not suffice for efficient ventilation, even with air-tight compartments. The amount of air brought down by the movements of the cages, and by diffusion, may provide ventilation for the plats and neighbouring parts of the workings in the shallow mines, but not in the deep ones, as, for example, take the New Chum Railway. It is a point worthy of consideration that, if a company does not arrange for shaft and winzes to go down simultaneously, whether it should be allowed to sink deeper. There are additional reasons for sinking winzes. By their means effective prospecting of the ground is secured, for in this way many rich reefs have in the past been discovered. Barren ground is a conclusion sometimes arrived at on insufficient data. The circumstances of one mine are not always similar to its neighbour. The Bendigo reefs are not continuous, frequently they only exist in one lease and not in the adjoining one. On this account also the workings do not run into each other at every level, and even though the reef continues into the next mine, it may not be payable. Thus, though always advantageous for ventilating purposes, the connecting of one mine with another is not always attainable except at a considerable expense. Provided, however, it is done always where practicable, the instances will be few and far between where drives will be needed solely for ventilation purposes if the winzes are sunk along with the shaft, and the air directed to the workings by doors and other means. The difficulty could be overcome if several mines could be ventilated as a group.

Whilst fully recognising the difficulties in which mine-owners and managers find themselves in some instances, on account of previous oversights, each mine should now be ventilated on the above principles, according to its requirements and opportunities.

It is not necessary to compel mines to go back and sink a series of winzes where they have been omitted, for probably a connexion with an adjoining mine could be made more readily and at less expense. Till this connexion has been effected it would be wise to use temporarily the inferior method of ventilation by some artificial means, and it should be definitely understood that hereafter no shaft shall be sunk without the winze going down at the same time, whether the ground is barren or not.

The general consensus of opinion amongst the miners and managers is that cross cuts should be driven from the shaft at every 100 feet, whilst some managers consider that only 80 feet should be the maximum interval

allowable. This does away with the neeessity for the high rises that have been put up in the past.

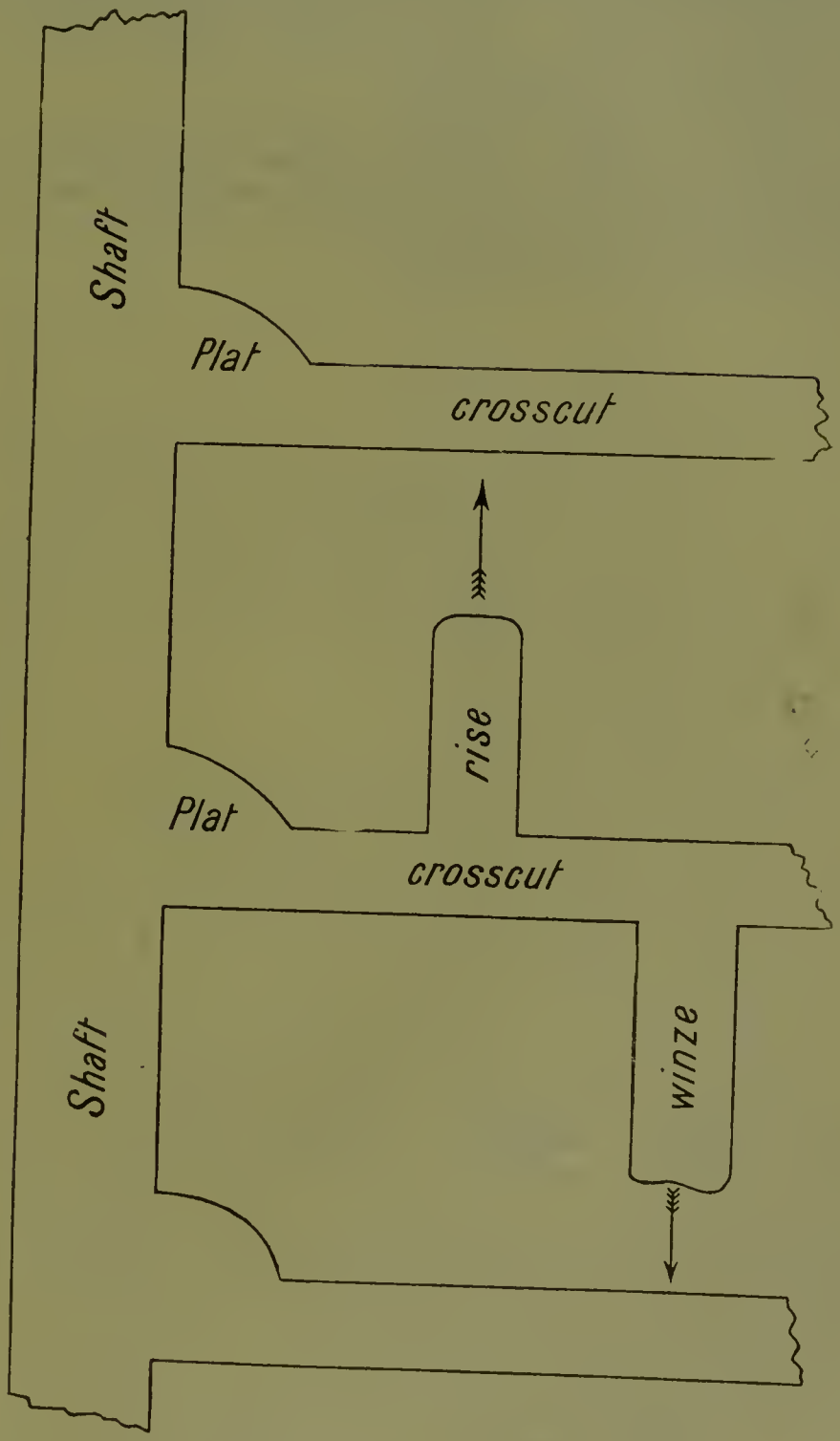


Diagram of plat, cross-cut, rise, and winze.

Again, with regard to the distance from the shaft at whieh the winze is sunk, either for purposes of ventilation or for prospecting, a distanee of more than 150 feet along the eross-eut is inadvisable. This restriction does not seem to be unreasonable. The most economieal position, of eourse, is in the centre country.

The policy of the Mines Department has been to require complianee with the law without harassing the mines needlessly ; but, though many managers

so plan the workings that the health of the miners is considered, in other cases this has not been sufficiently borne in mind, and, consequently, the ventilation is far from good. It seems necessary that not only should the supply of adequate ventilation be made compulsory, but also a definite plan should be submitted as to how it should be brought about, and this plan be followed as rigidly as circumstances permit.

The winzes for ventilation should be as much as possible vertically beneath each other. With the discovery of auriferous quartz further away, other connexions will be made. The nearer ones should be closed, to force the air current into the more distant workings. The cooling effect of this air current on hot drives is much appreciated.

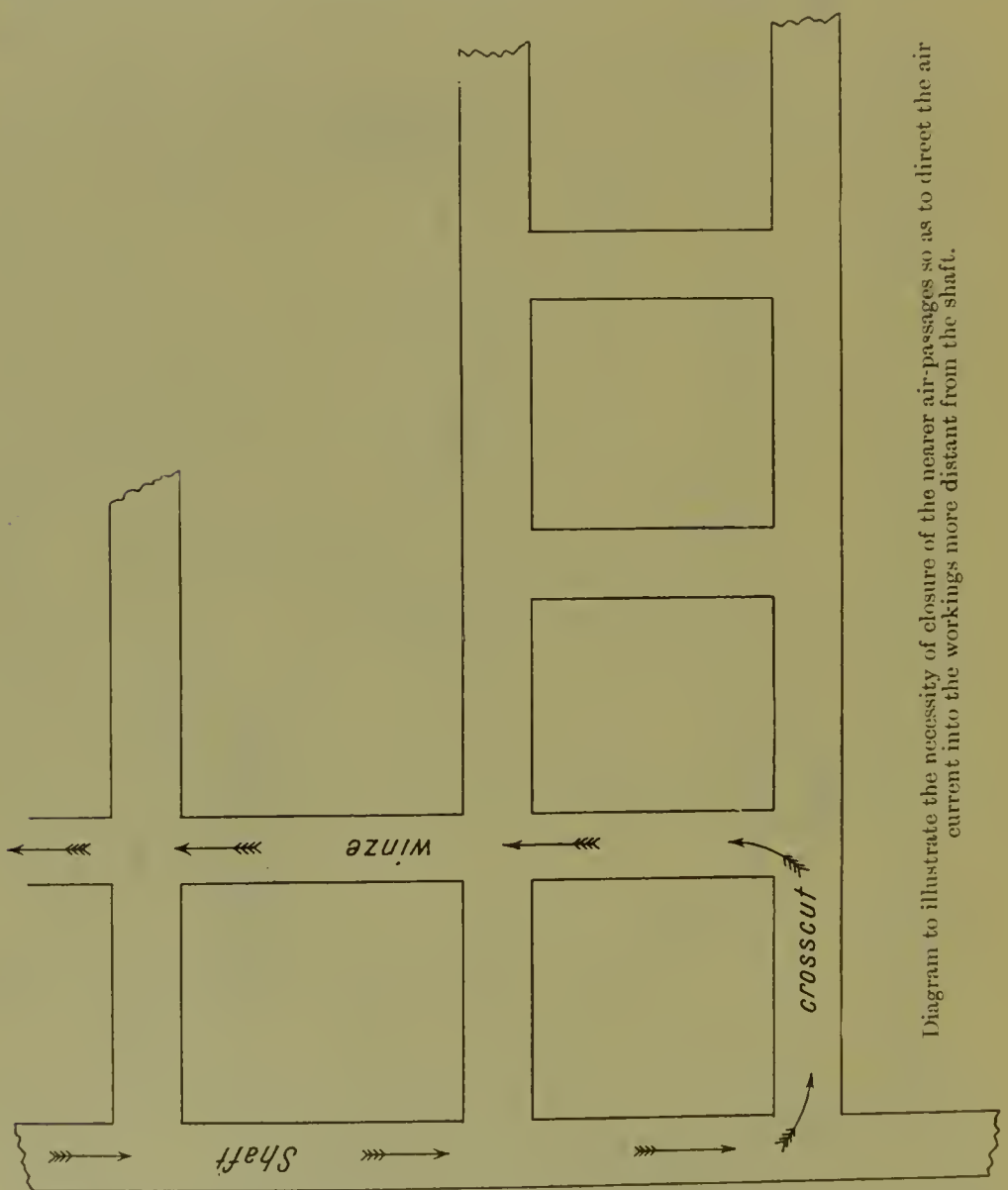


Diagram to illustrate the necessity of closure of the nearer air-passages so as to direct the air current into the workings more distant from the shaft.

Developmental work is continually going on ahead of this air current in the ends of drives, cross-cuts, winzes, and rises, which, but for the exhaust air from the rock drills, at present are not ventilated, save by diffusion. Here it is that the greatest difficulties are experienced, and they are veritable death traps to the miner. In these places the use of some mechanical appliances is necessary.

Rises merit special attention, as they are unanimously considered the most detrimental to health. They are also the most hazardous to work in, and various devices are arranged to improve them. Of these, the so-called "box" system, or division into three compartments, with the centre one filled with

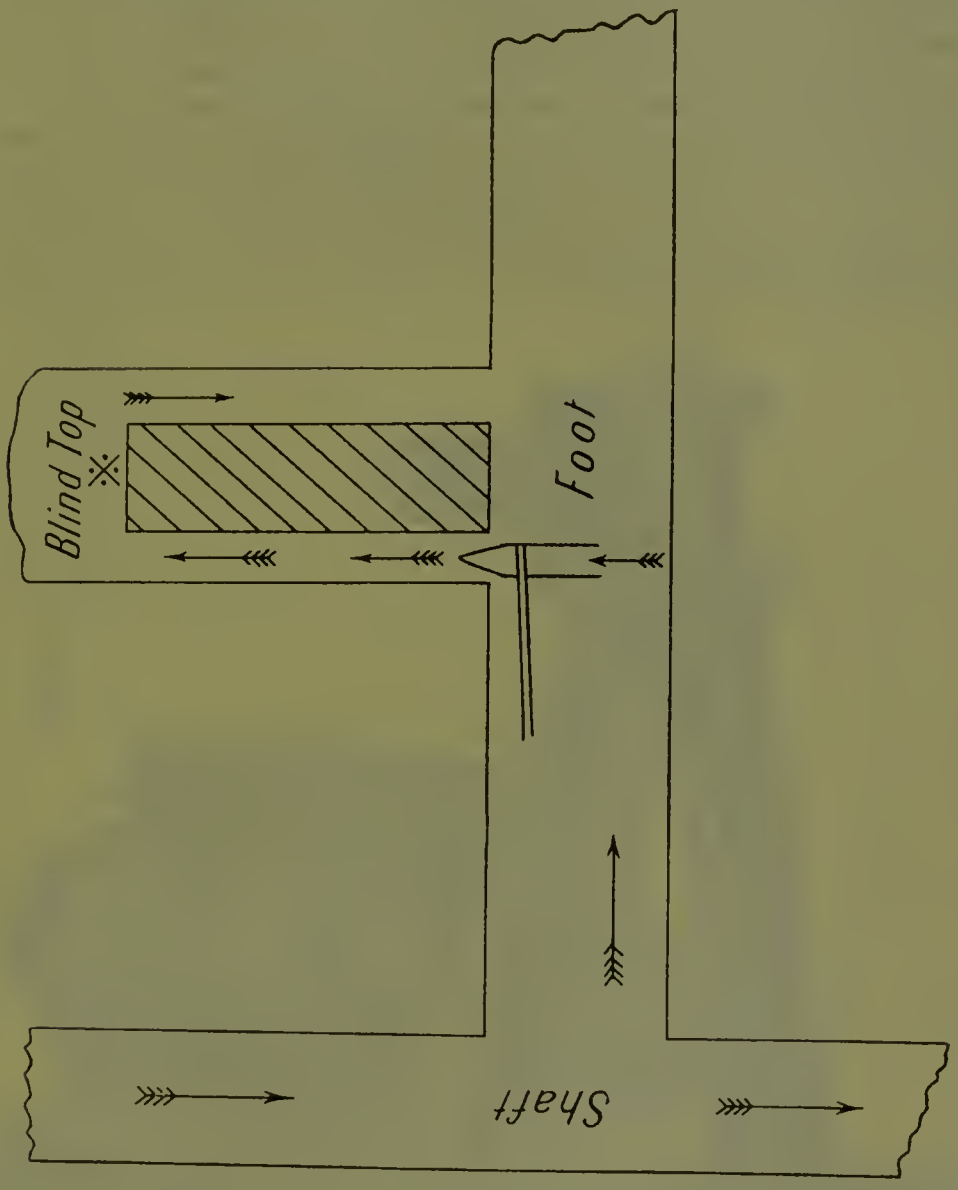


Diagram of "Cox" rise (3 compartment), with air jet at foot and arrows indicating air current.
* Site where men work with rock drill.

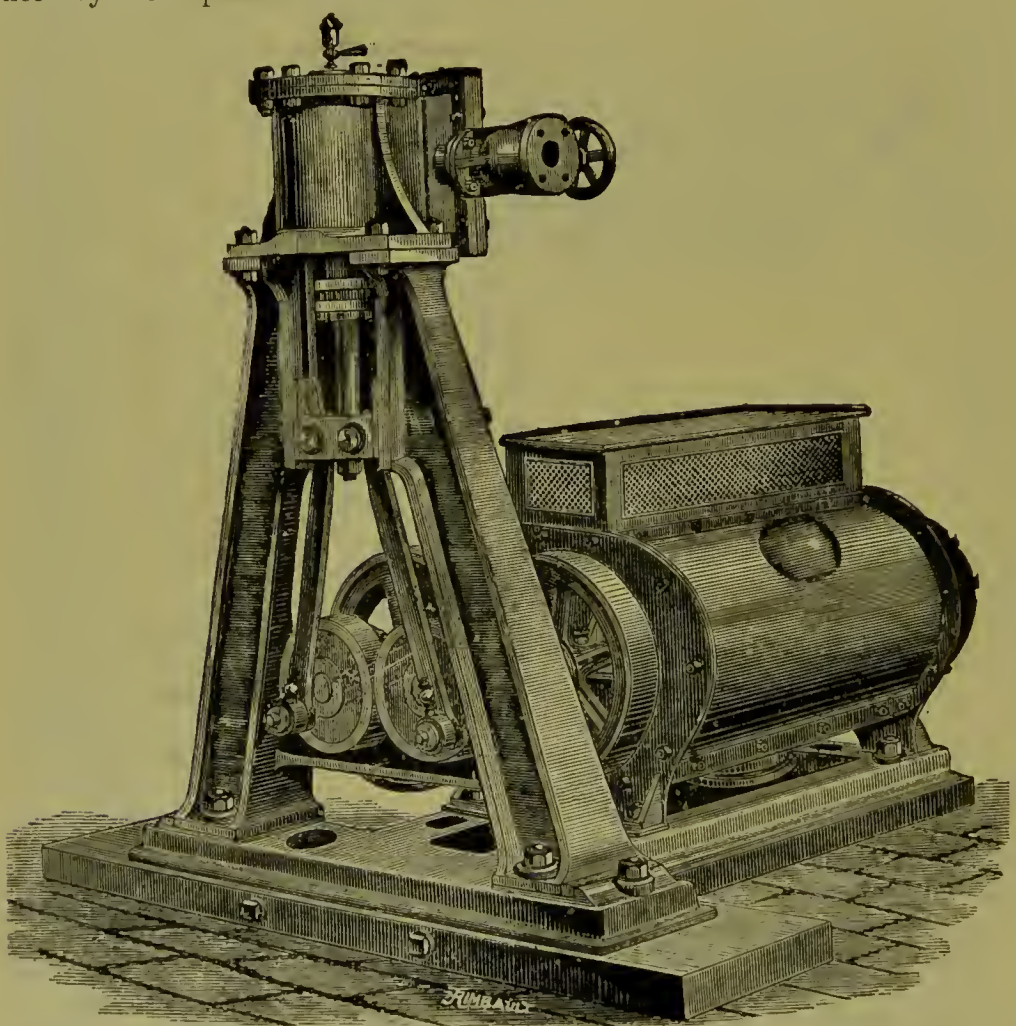
mullock, seems best. It is safer, less expensive for rises of any height, and, in addition, lends itself better to ventilation, a current of air being forced up one compartment (the ladder-way) and escaping by the third, down which the rock is thrown. The men are working in a small space (x), and unless the air is constantly changed, it is soon not fit for respiration. Nothing but a cool current of air can bring about a satisfactory condition of hygiene in these places. The proposal to bore several guiding holes, as it were, through the ground where the proposed rise is to go seems very feasible, and an additional means of ventilation.

The mechanical contrivances necessary to secure good air are of the simplest nature, while the motive power is always at hand in the compressed air. The two methods (wet and dry), as used in the Suffolk United Mine, have been described and figured before. In the air-jet machine the smaller the hole for the escape of the compressed air the greater the volume of mine air sucked up by a given volume of compressed air.

Instead of using it to blow air up a rise it may be placed down a winze to draw air out by suction. The cost of the apparatus is small, and the amount of compressed air used negligible in comparison with the benefits gained. If the ventilating pipe produces too much resistance by being unusually long, several jets may be inserted at different levels. Thus, excess of pressure may be obtained and consequent loss through leakage can be avoided.

Compressed air may be availed of in this manner far more usefully than by blowing it directly into the face. It has been computed that the amount of air forced in is about 30 times the amount of compressed air used.

Of other machines, especially those on a large scale, the Roots' Blowers have been much utilized with great success elsewhere. In the West Berry Consols Mine, at Allendale, the manager (Mr. Squire) says, "before the installation of the Blowers the men lost two or three days a fortnight owing to the ill effects of the gases in the mine, whereas now the gases are kept in check by the improved ventilation."



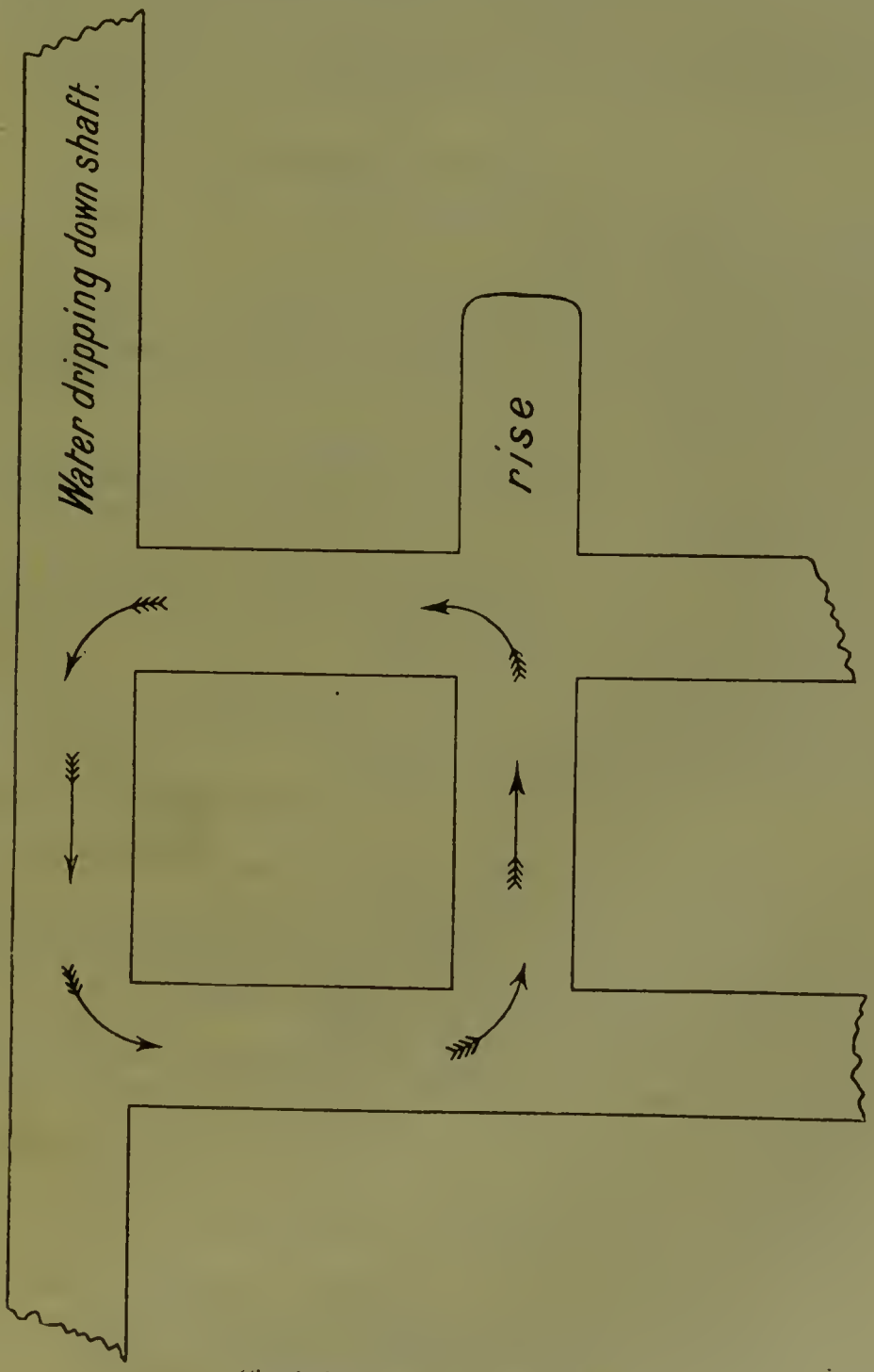
Picture of a Roots' Blower, as used in Victorian alluvial gold mines.

The blowers, however, give one the impression that, though suitable for an alluvial mine where there are only a few working faces, if the air current is much split up the friction of the smaller pipes to a large extent decreases the air current. Thus, this method would be efficient for a mine at Bendigo in the early stages of developmental work, or temporarily till a connexion with a neighbouring mine is effected.

It seems better to blow air in rather than to exhaust (except, perhaps, in winzes). For though in an exhaust system noxious fumes are directly

removed, air already moist and warmed takes their place; whereas in the blast systems cool air is carried directly in from the plat or surface, and the temperature of the end is more effectively reduced. Also the air current travels some distance ahead of the pipes right into the fumes.

In some mines, notably those without connexion with any other shaft, or in workings below this connexion, with an imperfect system of winzes, with dripping water in the shaft, the air is cooled, and hence after circulating throughout the lower levels becomes heated, ascending through what few winzes there are. Reaching the shaft again it is subjected to the same cooling effect of the water, and thus it circulates throughout the mine again and again, as can be seen by the diagram.



Circulation of air, but no ventilation.

With the anemometer it is shown that sufficient air is circulating, and it is difficult to convince the manager that the mine is not well ventilated.

No mechanical contrivances should wholly take the place of natural ventilation by winzes, cross-cuts, and drives to adjoining mines. Artificial means are only suitable to supplement the natural, and act as temporary expedients till the latter can be brought about. The faces should in no place be more than 150 feet from the natural air current. The more common adoption of artificial means where needed will lead to a saving of labour and a true economy in prolonging the life of the miner. The inability for sustained exertion would be diminished, and the miners would not be compelled to cease work at the end of every half-hour "to cool." Dr. Haldane, in a report on health of Cornish miners, says :—"A man cannot, and in any case will not, do a full day's work in air which is both warm and very moist, and, where possible, temperatures above 75° or 80° Fahr. should not be exceeded."

CONCLUSIONS AND RECOMMENDATIONS.

1. The rigid enforcement of Section 45, Rules 2 and 3, of the Mines Act, treating of the allaying of dust.

2. The adoption of a higher standard of ventilation to the effect that the amount of carbon dioxide in the air in any working places of the mine, or in the approaches thereto, shall not exceed fifteen parts by volume in 10,000, provided that the air taken for examination be not collected till half-an-hour has elapsed since firing.

3. It is unnecessary to demand that a definite or fixed volume of air be supplied to the faces, for the quantity is only a means to produce the quality that is to maintain the proportion of carbonic acid gas at less than fifteen parts by volume in 10,000.

4. In addition to the rough estimation of the carbon dioxide by the Inspectors below ground, provision should be made for a more accurate analysis of the mine air when, in the opinion of the Inspector, the inadequacy of the ventilation demands such examination.

5. The best system of ventilation is that secured by the simultaneous sinking of winzes with the shaft, and, as this has been neglected in the past, there is need that it be enforced by legislation.

6. The vertical distance between crosscut levels should not exceed 100 feet.

7. No working face should be at a greater distance than 250 feet by the travelling road from the natural air current.

8. Where the mine is badly ventilated from neglect to provide proper air courses, temporary mechanical appliances should be installed until a connexion can be made with an adjoining mine, or a regular system of winzes, to serve as either upcast or downcast channels, provided.

9. In the portions of the mine beyond the circuit of natural ventilation some assistance by the use of mechanical appliances is necessary for adequate ventilation.

10. The three-compartment or "box" system of "rising" is the method recommended.

11. Compressed air is not sufficient for ventilation, but is a useful aid, and no harmful effects result from it.

12. Suitable cleanly sanitary receptacles and arrangements should be provided underground in case of necessity, and it is imperative that any one polluting the workings with faeces shall be liable to a penalty. Similar receptacles are also necessary for waste food.

13. It is recommended that a medical inspector of mines be appointed. The want of such a man is widely felt. The duties of such a medical inspector to include—

(*a*) reports on the hygienic state of mines.

(*b*) *post-mortem* examinations when necessary, and the examination of localities at which an accident has occurred.

(*c*) the examination of miners suspected to be suffering from tuberculosis or other communicable disease.

(*d*) to perform other duties as they may arise.

14. No miner suffering from tuberculosis or other infectious disease be allowed to enter the underground workings, and no manager shall employ such a person knowing that he is so affected.

In the report little mention has been made of the deficiency of oxygen. This is proportional to the increase of carbon dioxide. This slight diminution has no physiological effect by itself. Again, it is futile to speak of the absence of sunlight, as such a want is irremediable.

The above report embodies the opinions I have arrived at, after a careful and earnest study from a medical and mining point of view of the ventilation problem on the Bendigo gold-field. It must be noted that the present Mines Act treats of all mines alike; no difference is made between alluvial and quartz mining. My report deals only with the Bendigo mines, and the above recommendations are intended to apply solely to these mines. The recommendations are those I deem necessary to insure adequate ventilation, and, where this is not possible by natural currents, mechanical means must be adopted at a cost commensurate with the continuance of the mining operations.

The miners are doing the work, and it is only fair that the conditions under which they labour should be ameliorated as much as possible.

I have the honour to be,

Gentlemen,

Your obedient servant,

WALTER SUMMONS.

By Authority: J. Kemp, Acting Government Printer, Melbourne.